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of
The Franklin Institute

DEVOTED TO

SCIENCE AND THE MECHANIC ARTS

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Journal
of
The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 202 JULY, 1926 No. 1

THE ELIMINATION OF WASTE IN INDUSTRY.*

BY

WILLIAM CHATTIN WETHERILL,

U. S. Department of Commerce, Washington, D. C.;
Department of Mechanical Engineering, University of Pennsylvania;
Member of the Institute.

When Benjamin Franklin was engaged with his colleagues in laying the foundations on which this nation has been built, the estimated value of the world's wealth was 100 billion dollars. This estimate represents man's margin of productive effort beyond daily food and shelter, accumulated after more than forty centuries of civilization. In the 150 years intervening, man has so increased his ability to produce, that the estimate stands to-day at 1000 billion dollars.

So great a change as this in man's economic condition must of necessity have introduced great changes in his way of living. A brief thought on our own individual experiences will emphasize the truth of this and give some idea of the rapidity at which these changes take place to-day.

Mr. Booth Tarkington, in his novel "The Magnificent Ambersons," gives a very vivid description of life in a midland town about fifty years ago. In order to get the proper perspective on what is to follow, it would not be amiss to call this picture to mind. Among other items that are of interest in this description, in view of the changes that have been wrought therein, Mr. Tarkington mentions "the little bunty street car on the long,

* Presented at a meeting held Thursday, March 11, 1926.

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single track that went its troubled way among the cobblestones. At the rear door of the car there was no platform, but a step where passengers clung in wet clumps when the weather was bad and the car crowded. The patrons, if not too absent-minded, put their fares into a slot; and no conductor paced the heaving floor, but the driver would rap remindingly with his elbow upon the glass of the door to his little open platform if the nickels and the passengers did not appear to coincide in number. A lone mule drew the car, and sometimes drew it off the track, when the passengers would get out and push it on again. They really owed it courtesies like this, for the car was genially accommodating; a lady could whistle to it from an upstairs window, and the car would halt at once and wait for her while she shut the window, put on her hat and cloak, went downstairs, found an umbrella, told the 'girl' what to have for dinner, and came forth from the house. The previous passengers made little objection to such gallantry on the part of the car: They were wont to expect as much for themselves on like occasions. In good weather the mule pulled the car a mile in a little less than twenty minutes, unless the stops were too long; but when the trolley car came, doing its mile in five minutes and better, it would wait for nobody. Nor could its passengers have endured such a thing, because the faster they were carried the less time they had to spare!" The more hurry, the more need for hurry! Manufacturing concerns have specialized on the inculcation of this doctrine in their industries until it has become not only a science in itself, but the father of new sciences. The doctrine has spread throughout our entire national life, and has precipitated us into a veritable maelstrom that seems to be continually accelerating. The punch press, the automatic machine, the automobile, the telephone, telegraph and radio, modern high-speed transportation equipment and a host of similar developments all stand as monuments to the importance of accomplishing things in less time. Even our social existence has become one continual hurry, and to cap the climax of our sojourn on this earth, we are hurriedly motored to our final resting place at a speed which is often in excess of that allowed by law.

Coincident with the developments that have brought about these changes there has been a constantly increasing complexity in our civilization—a complexity that has forced us to turn to specialization to meet the demands placed upon us by an ever-

growing fund of human knowledge. This complexity has manifested itself in industry with great emphasis, and has finally forced the modern business executive to give deep thought to the economic conditions created thereby.

In addition to these changes, the increasing complexity of modern times is causing a great increase in our mutual dependence. The time has gone by when an individual can shut himself off from his environment and emerge at the end with any satisfaction, and it is equally true that the day has gone by when an industrial group can successfully turn a deaf ear to the call for mutual coöperation without doing great harm to the industry at large of which it is a part. The lack of such coöperation in industry in the past, entailing as it does the ignorance of one group concerning the problems of other groups, has, as will be seen in what follows, given rise to industrial waste, the magnitude of which is appalling.

Secretary Hoover, in his foreword to the report of the Committee of the Federated American Engineering Society on waste in industry, says:

"We have probably the highest ingenuity and efficiency in the operation of our industries of any nation. Yet our industrial machine is far from perfect. The wastes of unemployment during depressions; from speculation and over-production in booms; from labor-turnover; from labor conflicts; from intermittent failure of transportation of supplies, of fuel and power; from excessive seasonal operation; from lack of standardization; from loss in our processes and materials—all combine to represent a huge deduction from the goods and services that we might all enjoy if we could do a better job of it."

The importance of this report, from the standpoint of its influence on the problem of industrial waste, is hard to overemphasize. With its details we cannot here be concerned. It has been published in book form and will amply repay anyone interested in this important matter for the time spent in reading it.

The purpose of the investigation was to supply a foundation on which corrective measures might be based and to point the way to future studies. It is to be particularly noted that the object was not to secure an absolutely accurate evaluation of the exact magnitude of industrial waste, but to secure a sufficiently accurate measurement thereof to indicate the nature of existing waste and

to disclose the basic facts necessary to intelligent action leading to the elimination of wasteful practices. With this end in view six major industries were selected as presenting a fair representation of industry as a whole. They included the building trades, men's ready-to-wear clothing, boots and shoes, printing, metal trades, textile manufacturing. In addition to the industrial studies, the report included considerations of a statistical nature dealing with unemployment, strikes and lockouts, legal machinery for adjusting disputes, industrial accidents, health of industrial workers, eye conservation, and purchasing and selling policies.

In view of the influence that the report has had on the waste-elimination work that is now being carried out under Secretary Hoover's direction in the Department of Commerce, it would be well to consider the attitude of the committee to the problem, and the significance they feel can justly be attributed to their findings. The first two paragraphs of their report are as follows:

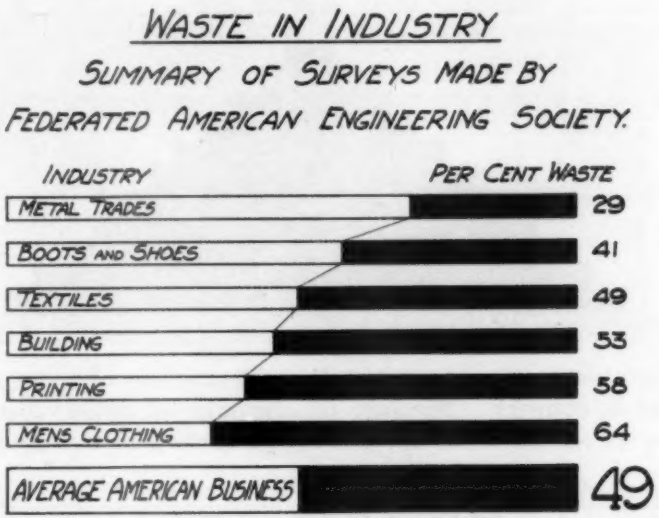
"In making the studies upon which this report is based, and in preparing the report itself, there has been no purpose or desire to place blame upon any individual, group or class. The wastes revealed are the result of methods, tactics, practices and relationships of long standing in industry, and the Committee has merely desired to indicate the main opportunities for eliminating waste and to show whose opportunity or responsibility it may be to adopt proper measures for such elimination.

"No attempt has been made to write an academic definition of waste or to speculate in regard to ultimate savings. For the purpose of this report no attempt has been made to consider all economic wastes. Rather, in the Committee's investigations, industrial waste has been thought of as that part of the material, time and human effort expended in production represented by the difference between the average attainments on one hand and performance actually attained on the other, as revealed by the detailed reports. In assaying waste in industry the Committee has undertaken to evaluate this difference. Thus it has established no theoretical standard of performance or excellence, but has developed a method of measurement to determine the degree of effective use of those factors within which it was believed waste might be discovered. It has conceived that a given practice is not wasteful until a better has been revealed, and that the value of a newer practice, or the amount by which it is an improvement over an earlier one, can only be determined by units and methods of measurement."

The results of the investigations of the committee are shown in Fig. 1. It is extremely important to realize that these figures do not completely represent the conditions and it would be dangerous even to consider them as representing the relative efficiency of the industries studied. Their value lies in the fact that they

not only point out the existence of industrial waste, but they force upon us the conviction that this waste bill is enormous.

FIG. 1.



The gross volume of business done in this country annually is in excess of $60,000,000,000. If we were to apply the average

FIG. 2.

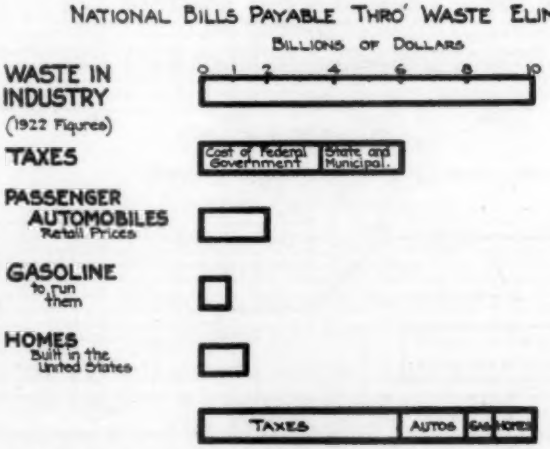
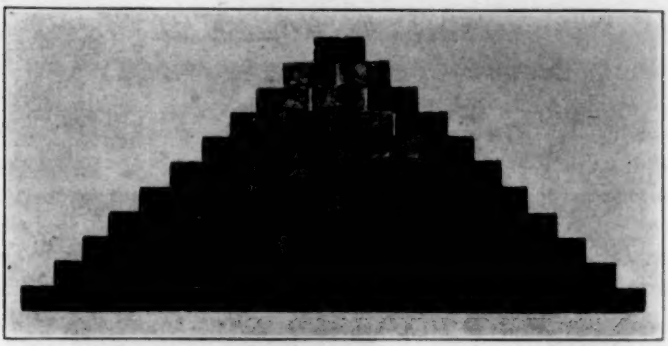


figure of 49 per cent. as indicated by the committee, we would be confronted by an annual waste bill of $30,000,000,000, and

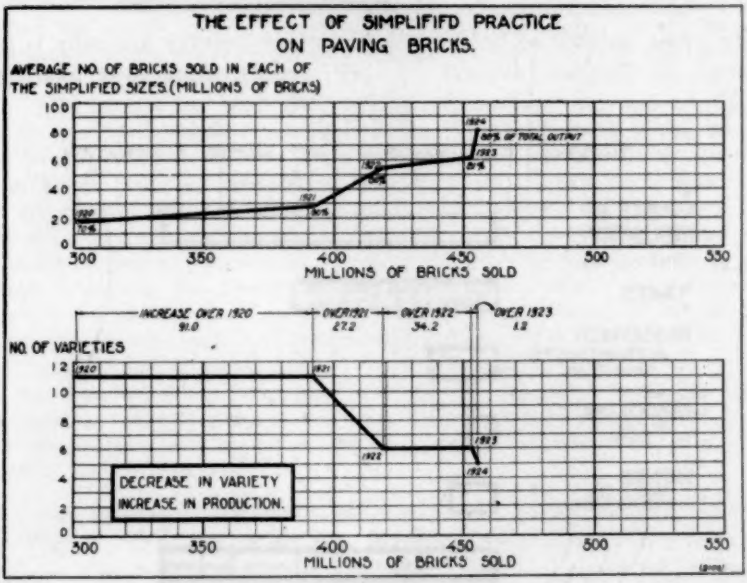
while it is true that we are here using the committee's figures in a way that is foreign to their purpose, a way for which we can

FIG. 3.



find no justification, we cannot deny the existence of an enormous waste in industry. Suppose, for the sake of conservatism, we place the annual waste in industry at one-third of this figure, we

FIG. 4.



still have a waste bill of $10,000,000,000 per year. Fig. 2 attempts to give some idea of the magnitude of this sum. The federal

and state taxes, the retail price of all passenger automobiles, the purchase price to the consumer of the gasoline required to run these automobiles, and the cost of all homes built in the United States in 1922 are together equal to $10,000,000,000.

The first item of waste in industry to which Secretary Hoover

FIG. 5.

TO THE MANUFACTURER

LESS CAPITAL TIED UP IN

RAW MATERIALS
SPECIAL MECHANICAL EQUIPMENT
SEMIFINISHED STOCK
FINISHED STOCK
STORAGE SPACE
REPAIRS PARTS

turned his attention when he went to Washington in 1921 had to do with simplification. The experience of the War Industries Board, of the committee on waste and of a vast number of indus-

FIG. 6.

TO THE MANUFACTURER

MORE ECONOMICAL MANUFACTURE THRU

LESS IDLE EQUIPMENT
BETTER SCHEDULING OF WORK
ACCURATE COST ACCOUNTING
LONG RUNS ON LARGE UNITS
SIMPLIFIED PACKING
SIMPLIFIED MATERIAL INVENTORY
REDUCED COST PER UNIT

trial executives indicated the necessity of cutting down the useless variety that exists in the common articles of trade. Consequently, there was established in the Department of Commerce a new unit which Secretary Hoover called the Division of Simplified Practice, whose duty it should be to investigate the existing diversity

of these common articles and coöperate in plans for securing their simplification.

The manufacturers and distributors of paving bricks were selected as the first group in which to carry out the plan, as the Division had been advised by the McGraw-Hill publications that

FIG. 7.

TO THE MANUFACTURER

MORE EFFICIENT LABOR THRU

LESS SEASONAL EMPLOYMENT FLUCTUATIONS
INCREASED INDIVIDUAL OUTPUT
GREATER SKILL OF WORKMEN
EASE OF TRAINING EMPLOYES
SIMPLER AND BETTER INSPECTION
SMALLER LABOR TURNOVER
GREATER EARNING POWER

here was a fertile field. Accordingly, a letter was written to representative members of the industry requesting an expression of opinion, the response to which resulted in calling a conference

FIG. 8.

TO THE DISTRIBUTOR

INCREASED TURNOVER DUE TO

CONCENTRATION OF STOCK
STAPLE LINES, EASY TO BUY, QUICK TO SELL
NO SLOW-MOVING NUMBERS
MORE EFFECTIVE SALES FORCE
MORE CONCENTRATED SALES EFFORT

in Washington to discuss the matter. At this conference a committee, composed exclusively of members of the industry, was appointed to make a survey and determine to what extent diversification existed. The survey disclosed the fact (Fig. 3) that there were sixty-six different sizes of paving brick being manu-

factured and that 75 to 80 per cent. of the total business each year was done in relatively few of these sizes. A general conference of the industry was then called to consider the findings of the committee and draw up a recommendation. Invitations were sent to all the manufacturers, distributors and consumers of whom

FIG. 9.

TO THE DISTRIBUTOR

DECREASED CAPITAL REQUIREMENTS

FEWER COMPLETE LINES TO CARRY
FOR MAINTENANCE STOCKS
FOR PACKING MATERIALS
FOR STORAGE SPACE
FOR INTEREST AND OTHER CHARGES
LESS OPERATING MARGIN
REQUIRED

any record could be found. A recommendation was drawn up and adopted at this conference, reducing the number of sizes from sixty-six to eleven, and the department was requested to conduct

FIG. 10.

TO THE DISTRIBUTOR

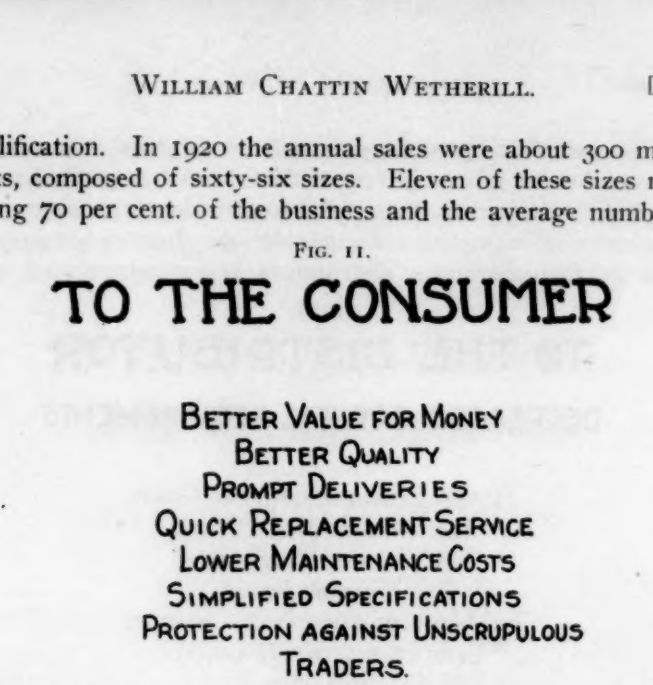
LESS OVERHEAD AND BETTER SERVICE

THRU LOWER HANDLING CHARGES
LESS STOCK DEPRECIATION
SMALLER CLERICAL FORCES
LESS OBSOLESCENSE
QUICK AND RELIABLE DELIVERY
FEWER MISUNDERSTANDINGS AND
ERRORS

a referendum by mail leading to its adoption. This referendum brought in acceptances of over 80 per cent. of the industry to the recommendation, whereupon the Department of Commerce published the recommendation in its Elimination of Waste Series. Fig. 4 shows the statistics of the industry before and after

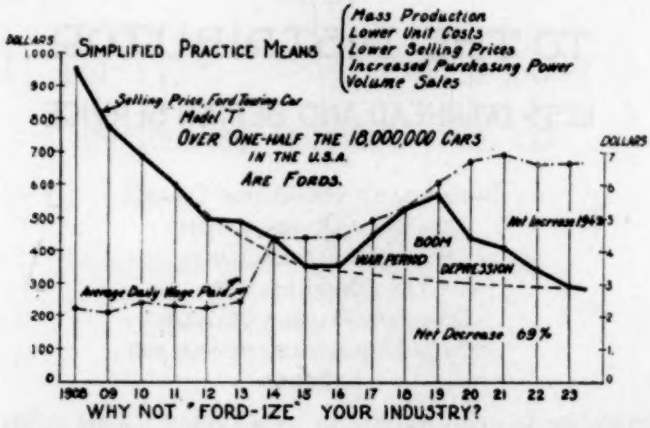
simplification. In 1920 the annual sales were about 300 million bricks, composed of sixty-six sizes. Eleven of these sizes representing 70 per cent. of the business and the average number of

FIG. 11.



bricks sold in each of the eleven sizes was just under 20 million. At the end of 1921 the sales in the recognized eleven sizes rose to 80 per cent. of the total business, the yearly output had

FIG. 11*a*.


SIMPLIFIED PRACTICE MEANS
Mass Production
Lower Unit Costs
Lower Selling Prices
Increased Purchasing Power
Volume Sales
Selling Price, Ford Touring Car Model "T"
OVER ONE-HALF THE 18,000,000 CARS IN THE U.S.A. ARE FORDS.
Average Daily Wage Paid by
Net Increase 194%
Net Decrease 69%
BOOM
WAR PERIOD
DEPRESSION
DOLLARS
1908 09 10 11 12 13 14 15 16 17 18 19 20 21 22 23
WHY NOT "FORD-IZE" YOUR INDUSTRY?

increased to 390 million bricks and the average number of bricks used in each of the eleven sizes was 29 million. At this point a revision conference was held and the number of recognized sizes was cut to six. The gross business went to 419 million bricks

and the average number of bricks sold in each of the six sizes rose to 55 million with 80 per cent. of the business represented by the six sizes. By the end of 1924 the total production had reached 455 million, 88 per cent. of which was done in five recognized sizes and the average number of bricks sold in each of the five sizes had risen to 80 million.

Let us turn now to a consideration of some of the advantages to be secured through the application of simplified practice. Figs. 5, 6 and 7 show this for the manufacturer and Figs. 8, 9 and 10 for the distributor and Fig. 11 for the consumer. The estimated savings due to simplification of paving bricks, as the Division of Simplified Practice has been advised by the members of the industry, amount to $1,000,000 per year. (Fig. 11*a*.)

This, then, is the operation we call "Simplified Practice." Since the establishment of the division in the Department of Commerce in 1921, the following commodities have been simplified:

NOTE: Publications are available for all items on following list except those indicated by (*), and may be obtained from the Superintendent of Documents, Government Printing Office.

S. P. R. No.	Item.	Reduction in Varieties. From.	To.
1.	Vitrified paving brick. Fourth Revision Conference	66	4
2.	Beds, springs and mattresses	78	4
3.	Metal lath	125	24
4.	Asphalt (penetrations)	88	9
5.	Hotel chinaware	700	160
6.	Files and rasps	1351	496
7.	Rough and smooth-face brick	75	2
	Common brick	44	1
8.	Range boilers	130	13
9.	Woven-wire fencing	552	69
	Woven-wire fence packages	2,072	138
10.	Milk bottles and caps	78	10
11.	Bed blankets (sizes)	78	12
12.	Hollow building tile	36	19
13.	Structural slates for plumbing and sanitary purposes	84 per cent. average reduction	
14.	Roofing slates, descriptive terms, thicknesses and sizes	98	48
15.	Blackboard slates, slab heights and sizes	251	25
16.	Lumber	Standard nomenclature grades and sizes for soft-wood lumber	
17.	Forged tools	665	351

S. P. R. No.	Item.	Reduction in Varieties. From.	To.
18.	Builders' hardware (items and finishes) ...	Reduced 26 per cent. and 71 per cent., respectively	
19.	Asbestos paper—sizes, widths, weights of rolls	14	8
	Asbestos mill board—sizes, thicknesses	10	5
20.	Steel barrels and drums	66	24
21.	Brass lavatory and sink traps	1,114	72
22.	Paper	Indeterminable	
23.	Plow bolts	1,500	840
24.	Hospital beds		
	Length	33	1
	Width	34	1 standard 2 specials
	Height	44	1
25.	Hot-water storage tanks	120	14
26.	Steel reinforcing bars—cross-sectional areas	40	11
27.	Cotton duck (widths and weights)	460	94
28.	Sheet steel	1,819	263
29.	Eaves trough and conductor pipe	21	16
30.	Terne plate (weights)	9	7
31.	Loaded shells	4,076	1,758
32.	Concrete building units (length, width and height of blocks, tile and brick)	115	24
33.	Cafeteria and lunch-room chinaware	668	177
34.	Warehouse forms	Thousands	15
35.	Steel lockers	65	17
36.	Milling cutters	35 per cent. average reduction	
37.	Commercial purchase forms	Thousands	3
42.	Paper grocer's bags	6,280	4,700
44.	Box board thicknesses	244	60

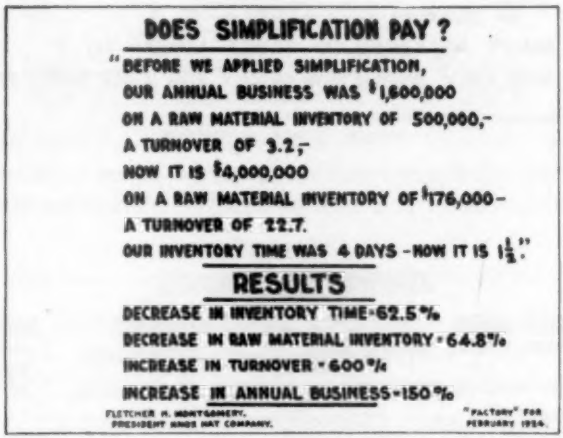
Simplified Practice Recommendations in Process of Acceptance.

S. P. R. No.	Item.	Reduction in Varieties. From.	To.
*38.	Sand line brick (length, width and height)	14	3
*39.	Dining-car chinaware	700	113
*40.	Hospital chinaware	700	113
*41.	Insecticides and fungicides (packages)	38	21
*43.	Paint and varnish brushes	480	138
*45.	Grinding wheels	715,200	459,400
*46.	Tissue paper—(roll tissue)	13	3
	Shoe tissue	21	6
*47.	Tacks and nails (sizes)	428	181
	Packing weights	423	121
*48.	Shovels, spades and scoops	4,460	384

S. P. R. No.	Item.	Reduction in Varieties. From.	To.
*49.	Sidewalk lights (sizes)	120	6
	Styles	80	5
	Shapes	10	2
*50.	Checks, notes, etc.	Thousands	One size for each instrument
*51.	Self-opening die heads	75 per cent. reduction	
*52.	Paint and varnish	House paint	
		32	28
*53.	Steel reinforcing spirals	7	3
*54.	Sterling silver flatware	190	62

In addition to the Simplified Practice Recommendations that have passed through the mill in the Division of Simplified Prac-

FIG. 12.


DOES SIMPLIFICATION PAY?
"BEFORE WE APPLIED SIMPLIFICATION,
OUR ANNUAL BUSINESS WAS $1,600,000
ON A RAW MATERIAL INVENTORY OF 500,000,-
A TURNOVER OF 3.2,-
NOW IT IS $4,000,000
ON A RAW MATERIAL INVENTORY OF $176,000-
A TURNOVER OF 22.7.
OUR INVENTORY TIME WAS 4 DAYS - NOW IT IS 1½."
RESULTS
DECREASE IN INVENTORY TIME-62.5%
DECREASE IN RAW MATERIAL INVENTORY-64.8%
INCREASE IN TURNOVER-600%
INCREASE IN ANNUAL BUSINESS-150%
FLETCHER H. MONTGOMERY,
PRESIDENT KNOX HAT COMPANY.
"FACTORY" FOR
FEBRUARY 1924.

tice, there are a number of individual simplifications which have been conducted by isolated industrial groups, and while it is true that these simplifications have lacked the essential characteristic of nation-wide acceptance in order to be productive of maximum benefit, they emphasize very clearly the advantages to be gained through the adoption of this principle. A few of these cases are shown in Figs. 12, 13, 14, 15 and 16. Fig. 12 shows what was accomplished by the Knox Hat Company. Fig. 13 shows the results of Simplified Practice in the hotel business. Fig. 14, the Remington Arms Company. Fig. 15, the Retail Drug Store. Fig. 16, garage.

The procedure which has been set up in the Division of Simplified Practice to carry on simplification is as follows: A letter

is received from a trade association or a manufacturer or a distributor calling attention to the existing diversification of a

FIG. 13.

A LARGE CHAIN HOTEL COMPANY
SIMPLIFIED ITS REQUIREMENTS, AND REDUCED
COSTS, OF ITEMS SIMPLIFIED, 20% BELOW FORMER COST,
RELEASED $350,000 FROM FORMER INVENTORIES,
AND SAVED $100,000 PER YEAR.

HOW?

BY REDUCING
30 STYLES OF GLASSWARE TO 10
15 DESIGNS OF CARPETS TO 3
MANY PATTERNS OF TABLE LINEN TO 1
AND SIMILARLY SIMPLIFYING NEARLY 200 OTHER SUPPLY ITEMS.

FROM STATEMENT BY L.M. BOOMER, PRESIDENT,
WALDORF-ASTORIA, INCORPORATED.

commodity and suggestion that steps be taken to eliminate the unnecessary items. The Department then writes to other inter-

FIG. 14.

REMINGTON'S RESULTS.

SHOT GUNS	FORMERLY	NOW
GUN STOCKS MADE BY HAND	70%	10%
" " " " MACHINE	30%	90%
MACHINES IN CONTINUOUS OPERATION	—	80%
SHELLS		
DAILY LOADING MACHINE CHANGES	230	84
DAILY IDLE MACHINE COSTS	$220	$80
DAILY SAVING = $140 22		
ANNUAL SAVING = $37,800 22		
REDUCTION OF WAREHOUSE SPACE = 42%		
INVENTORIES REDUCED = 65%		

"SIMPLIFICATION IS FOUNDED ON
THE BED-ROCK OF SOUND ECONOMICS!
UNNECESSARY MERCHANDISE IS AN ECONOMIC WASTE!
TO GIVE THE CONSUMER BETTER GOODS
AT LOWER PRICES, APPLY SIMPLIFICATION."

C. L. REIERSON
REMINGTON ARMS CO. INC.

FROM "FACTORY"
MAY 1924

ested parties, generally manufacturers, and requests an expression of opinion. If favorable replies are received in sufficient

number to warrant it, the Department calls a conference to secure general discussion of the problem and to suggest to the group the appointment of a Simplified Practice committee to make a

FIG. 15.

RESULTS OF SIMPLIFIED PRACTICE
IN
OPERATION OF A TYPICAL RETAIL DRUG STORE.

INCREASED		DECREASED	
TURNOVER	= 70%	INVESTMENT	= 14%
VOLUME OF BUSINESS	= 43%	INVENTORY TIME	= 67%
		INVENTORY COST	= 56%
WAGES - RATES	= 100%	PERSONNEL	= 58%

PAYROLL COST DROPT FROM 20% TO 11% OF SALES
RENT DECREASED FROM 14% TO 7% OF SALES

survey and establish the facts (frequently through the Trade Association Secretary). When this has been done, the Department is advised by the committee and a general conference is

FIG. 16.

A LARGE GARAGE COMPANY
SIMPLIFIED ITS EQUIPMENT TO
ONE MAKE OF MOTOR TRUCKS &
ONE MAKE OF PASSENGER CARS.

RESULTS

"REDUCED SPARE PARTS STOCK FROM 20 000 TO 5000 ITEMS,
REDUCED VARIETIES OF TIRES, OILS, GREASES, ETC.,
DECREASED STOCKROOM SPACE, PERSONNEL, AND INVESTMENT,
REDUCED PURCHASE PRICES, AND
REDUCED COSTS (NOT INCLUDING PAY OF DRIVERS)

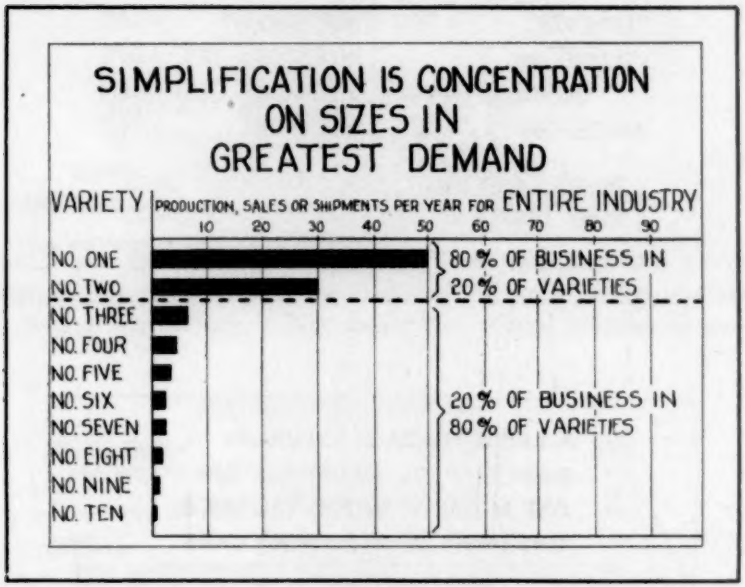
TWO CENTS PER MILE IN 1922 OVER 1921,
FIVE CENTS PER MILE IN 1922 OVER 1920."

L. M. STAFFELBACH, AUDITOR — THE GARAGE SERVICE COMPANY.

called, composed of manufacturers, distributors and users, to consider the evidence and adopt a recommendation. The Department of Commerce does nothing more than supply a neutral meet-

ing ground where open discussion can be carried on without fear of ulterior motives coming into play. It has no voice in the formation of the Simplified Practice Recommendation whatever. When the recommendation has been drafted and approved by the conference, the Department of Commerce sends a summary report thereof to all the manufacturers, distributors and users of the product it can locate and encloses in this summary an acceptance blank with the request that, if the action as embodied

FIG. 17.



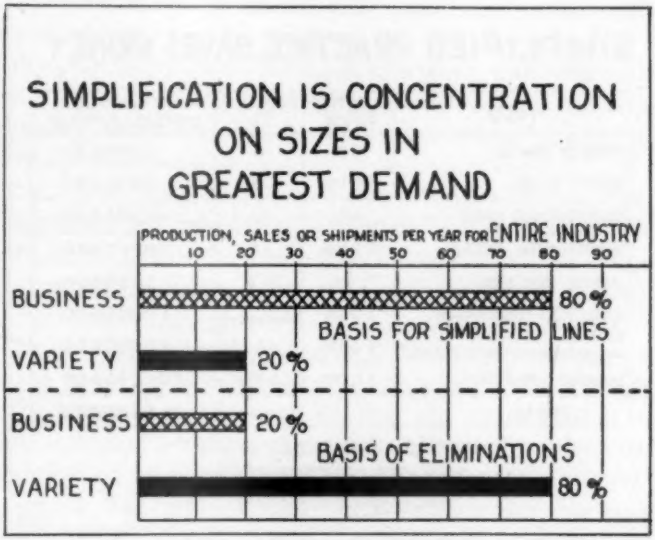
in the recommendation is satisfactory, this blank be signed and returned. It is only upon receipt of these executed acceptances from at least 80 per cent. by volume of the total yearly business done in the industry in each of the three groups that the recommendation is published by the Department of Commerce in its Elimination of Waste Series.

The general conference, in addition to drafting a recommendation, appoints a committee of manufacturers, distributors and users to represent the industry in the matter of simplification. This committee is charged with the duty of securing adherence to the recommendation, of receiving the criticism and comment concerning its satisfactory operation and of embodying construc-

tive criticism into subsequent revisions of it. This latter is a most important feature of the work because, as conditions change, demand changes and production and distribution must also change. The general conference recognizes this need and settles upon definite dates when revision conferences are to be held.

These recommendations work great changes in industry and time must be allowed for the changes to be brought about gradually. Manufacturers and jobbers must be given time for clearing

FIG. 18.



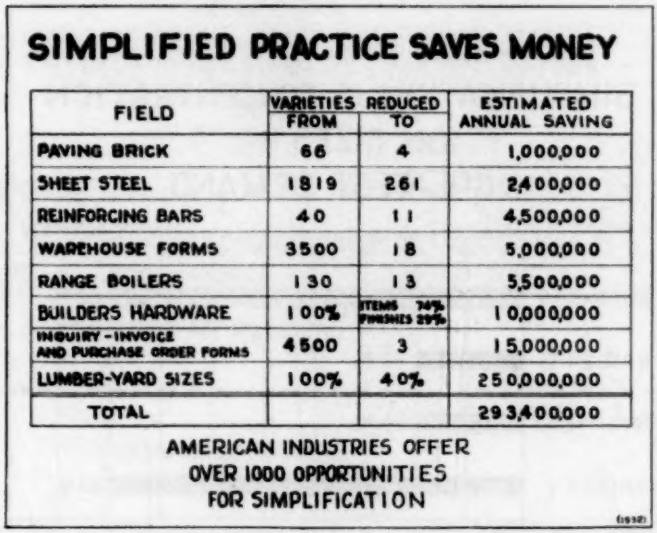
their stocks of abandoned sizes, for new production schedules to be put into effect, for the preparation of advertising literature and for similar readjustments. Consequently, it is necessary for the general conference to agree on a date far enough into the future to allow for these changes before a recommendation becomes effective.

A very significant fact has been demonstrated as a result of a large number of surveys in various industries leading to simplification, which is that over 80 per cent. of the business done in a great majority of these industries is in 20 per cent. of the varieties offered. This fact has been so repeatedly verified in the Division of Simplified Practice that it has become axiomatic. Figs. 17 and 18 show this diagrammatically. Fig. 19 shows some

of the estimates the Division of Simplified Practice has received from the industries which have availed themselves of its services. These figures have been supplied by the industries concerned; the Department has had no part in their compilation. Since they were compiled by individuals who unquestionably know their own business, they should not be far from the truth.

In order to secure the maximum benefit to be derived from Simplified Practice, the Department is planning the publication

FIG. 19.


SIMPLIFIED PRACTICE SAVES MONEY
FIELD
VARIETIES REDUCED FROM
TO
ESTIMATED ANNUAL SAVING
PAVING BRICK 66 4 1,000,000
SHEET STEEL 1819 261 2,400,000
REINFORCING BARS 40 11 4,500,000
WAREHOUSE FORMS 3500 18 5,000,000
RANGE BOILERS 130 13 5,500,000
BUILDERS HARDWARE 100% ITEMS 74% FINISHES 29% 10,000,000
INQUIRY - INVOICE AND PURCHASE ORDER FORMS 4500 3 15,000,000
LUMBER-YARD SIZES 100% 40% 250,000,000
TOTAL 293,400,000
AMERICAN INDUSTRIES OFFER
OVER 1000 OPPORTUNITIES
FOR SIMPLIFICATION

of a National Directory of Simplified Commodities. This will contain a list of all commodities that have been simplified through the coöperation of the Division of Simplified Practice, showing in detail the simplified sizes carried in stock. It should be of the greatest assistance to all those interested in problems of design, all purchasing agents and indeed the general public, as it will enable them to see at a glance what is available for immediate delivery.

The increase in volume of the work that it has become necessary for the Division of Simplified Practice to handle has necessitated the division of waste-elimination work into its industrial sub-groups. Such a group was established in May, 1925, in the wood-using industries, and in order to be certain that the work

would be carried on to the best interests of the industry, Secretary Hoover set up the National Committee on Wood Utilization to act as a Board of Directors to the waste-elimination work in the industry. It has now been necessary to segregate the metal-using industries in the same way, and there is at present in process of formation a National Committee on Metals Utilization, whose duties it shall be to act as a Board of Directors to the activities of waste elimination for the metal-using trades and to secure the coöperation and unity of purpose so necessary to its success.

This Committee of Metals will take under consideration any problems which, in the opinion of the Board of Directors, afford opportunity for increased efficiency and elimination of waste. Already there is under consideration the question of eliminating some of the diversification which exists in commodity specifications.

In August, 1925, the Bureau of Standards of the Department of Commerce published the National Directory of Commodity Specifications (Miscellaneous Publications, No. 65, August 28, 1925), which contains a list of over 27,000 specifications for some 5000 commodities.

The diversification disclosed in this directory strongly emphasizes the need for simplification in commodity specifications. It must be borne in mind, however, that the simplification of commodity specifications is a more technical problem than the mere elimination of slow-moving items from the channels of trade. The causes that underlie the diversification are fundamentally different in the first place and the resistance to simplification is more firmly intrenched. To make matters worse, this resistance is intrenched in the minds of technical experts, men who very properly defend their opinions as representing their professional ability.

Among the fundamental causes for diversification in commodity specifications, it will be well to consider the following:

First, the diversification that creeps in because of differences in individual professional experience. Just as great surgeons differ in technique, so engineers accomplish the same result through the application of different methods. These differences lead to the use of a given material under slightly modified conditions and hence, in view of the fact that the fabricators of the material are willing to meet the wishes of the designing engi-

neers, changes creep into the specifications that render the material more serviceable under the changed conditions.

Second, in order to increase the possible market for a product, the manufacturer will, through coöperation with a research department or otherwise, build up a great diversity in its product and publish much descriptive literature emphasizing the respective merits of each variety. This practice may be forced upon the manufacturer through similar action on the part of a competitor or may originate with him.

Third, through the very human characteristic that is not alone confined to specification writers, there exists the desire to create something a little different from all the rest, the desire to emphasize individual professional supremacy by the simple expedient of just being different. If an engineer is engaged to write specifications and merely employs his time selecting the best from existing specifications, there is a possibility that doubt will be expressed as to his ability to create something new, whereas, by originating a specification of his own, much professional prestige is to be obtained.

It can be argued that at least in the first and second causes enumerated there is an advantage to be gained through diversification. It stimulates invention, it broadens the field of the designer, it is productive of improved methods, it helps increase the sales volume, etc. But the fact remains that it increases the burden to the ultimate consumer through many channels, most of which have already been enumerated above. The elimination of the excessive and unnecessary diversification in commodity specifications is of first importance to American industry. There are no liabilities to dim the assets that are to be derived through such a practice if the task is intelligently performed.

The question logically presents itself: What is the proper and intelligent method of securing this result? How can all the conflicting interests be so adjusted that the essential condition of universal satisfaction will materialize? This is the problem that the National Committee on Metals Utilization of the Department of Commerce will attempt to solve. There is only one condition that is vital to its solution, and that is a desire on the part of the industrial groups involved to coöperate. To be not only ready and willing but eager to enter into the abolition of this great cause of industrial waste with the spirit of real coöperation unequivo-

cally adopted is the bed rock on which successful effort must rest. It is inevitable that such a condition will impose temporary individual hardships, but they will be insignificant when viewed in the light of future savings. An enterprising management will not hesitate to expend large sums for modern equipment in view of the reduced manufacturing cost that its installation will secure. In the case of simplification of commodity specifications the initial cost will be negligible, while the future benefits will be of paramount importance in maintaining a standard of living that has never before been equalled in the history of mankind.

It is well recognized that members of an industrial group engaged in competitive activity are always suspicious of the motives that prompt a member thereof in attempting a reform. In this fact is to be found the necessity for the participation of the Department of Commerce in the industrial waste campaign. It is essential that a neutral meeting ground be supplied by a totally disinterested party to the transaction. All of the waste-elimination work that is being carried on under Secretary Hoover's direction is based on the assumption that it is the function of Federal Government to coöperate with industry, not to interfere with nor dictate to it. To impress the industrial groups with the realization that our efforts are truly in accord with this doctrine has been, and continues to be, one of our major concerns.

Perhaps the most significant characteristic of modern industry is the increasing realization of mutual dependence. This fact becomes more apparent as the complexity of modern civilization increases. Its effect on industrial development is profound indeed.

We see trade associations and coöperative bodies in every industry, the functions of which are to promote better understandings, better team-work, better trade conditions that can only be brought about by coöperative action. It is seldom that participation by an individual in the activities of one of these organizations does not impose obligations upon him that not only deprive him of a portion of his leisure but require him to donate much of his energy as well. That these associations have continued to increase their usefulness year by year is proof of the need for the spirit which they exemplify in industry. They are waging war against suspicion, against malpractices, against conspiracy, against harmful collusion. A war that may be relied upon to

place industry on an ever-higher moral plane, a plane of ever-increasing usefulness.

There has been in evidence in the past an effort on the part of the Federal Government to correct the evils of industrial mismanagement by legislation. Some of this has been good, some very bad. It has all, however, created in the minds of industrial executives a horror of federal interference. The work of waste elimination, and particularly the participation of the Department of Commerce therein, is founded on an entirely different concept, which is that the executives of an industry know more about how to run that industry than does the Federal Government, and that if industry is to be properly and effectively governed, it must be by a government of industry, by industry, for industry. In the phases of industrial activities which are concerned with group interests and which are dependent upon mutual coöperation, with statistical information, with market conditions abroad and at home, there is presented an opportunity for governmental assistance available through no other agency.

In order to secure the continuation of the campaign against avoidable industrial waste that is now in operation, it is the aim of the Department to impart enough initial velocity to this undertaking to enable it to gather momentum from industrial support and eventually carry its own burden. There are two elements necessary to the achievement of this goal. The first is a sound economic foundation; the second, a realization on the part of industrial executives of their obligations not alone to their companies, but to their industries, the 10,000,000 workers of those industries, and to their nation—the future prosperity of which lies largely in their control.

Transmutation of Mercury into Gold. H. SHELDON and R. S. ESTEY. (*Phys. Rev.*, April, 1926.)—At the Montreal meeting of the American Physical Society in February these reported their failure to get gold when they repeated Miethe's experiments. They got no trace of gold at all "although a quantity fifty times smaller than Miethe claims to have produced in 197 hours was detectable with certainty." They adduce in addition a theoretical reason why Miethe's method cannot succeed in changing the number of electrons in the nucleus of mercury.

There might seem to be a geographical element in transmutation. It is accomplished, according to the claims made, in Asia and Europe, but in the Western Hemisphere no one can do it. G. F. S.

DIELECTRIC CONSTANT OF BROMINE.

BY

ARTHUR BRAMLEY, Ph.D.

Bartol Research Fellow.

BARTOL RESEARCH FOUNDATION
Communication No. 5.

IN RECENT work on the dielectric constant of a number of dipole vapors, anomalous increases in the dielectric constant were found as the liquefaction point was approached.[1] A similar increase was found by the writer for bromine vapor in equilibrium with its liquid phase at 23.4° C.[2] Jona and the writer attributed these results to the association of the molecules, while C. T. Zahn has regarded them as due to the formation of an absorbed layer of the liquid on the condenser plates used to measure the dielectric constant. With regard to the association of the molecules, this combination may be due either to the natural tendency of the molecules to condense or to the action of the electric field to form molecular aggregates. In order to investigate more fully these various possibilities a further study of these anomalies has been undertaken by the writer.

DESCRIPTION OF APPARATUS.

For the measurement of the variation of the dielectric constant with the vapor pressure of the bromine gas, an oscillating bridge method was employed. The apparatus used is shown in Fig. 1.

The oscillating system consists of a vacuum tube (U × 210 General Electric Company), two coils L_1 and L_2 coupled together, and two condensers C_1 and C_2, the values of the coils and condensers being so chosen that the circuit oscillates at a wave-length of about 500 metres. The condenser C_1 is fitted with a variable vernier condenser, while the plate batteries are shunted with a large capacity C, which allows the oscillations to travel through it without serious damping.

The bridge consists of four condensers, C^1, C^3, C^4, and C^5, arranged in the arms of the bridge. The capacity C^1 is connected in parallel with the test condenser C^2, in which is placed the dielectric whose behavior we wish to ascertain; the capacity

C^5 is also connected in parallel with a variable standard condenser C^6. The mid-points C and D of the bridge are connected through a coil L^1, which is coupled with L_1 and L_2. The points A and B are connected through a switch S with a coil L^2, which is coupled to the plate circuit by the coil L^3, L^3 being independent of L_1 and L_2. In the plate circuit is also connected in series a non-inductively wound variable resistance R which is connected to the potentiometer. The bridge, the oscillating circuit, including with it the coils L_1, L_2, L^1, L^2, and L^3, and the potentiometer

FIG. 1.

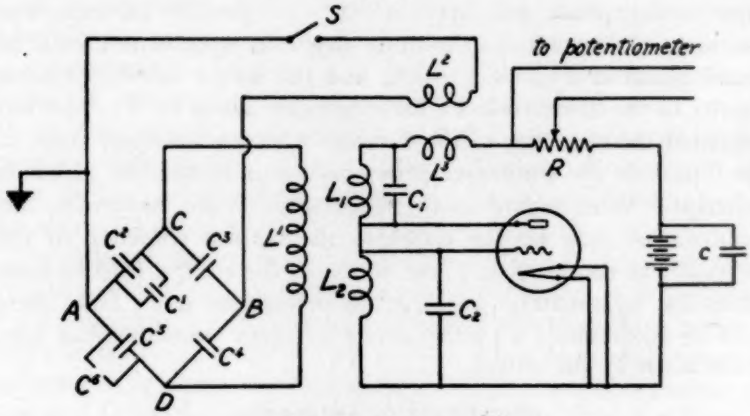


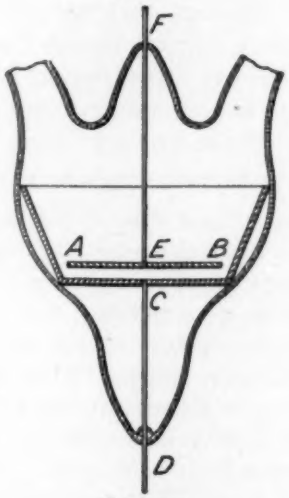
Diagram of apparatus.

are contained in separate metal boxes which are all earthed. The electric connections between the different systems are run through metal tubes so that all the circuits are screened from external influences. The condenser C^6 and the vernier condenser attached to C_1 can be worked from outside by means of bakelite handles; the switch S is also operated from the outside so as to avoid capacity effects. The condenser C^5, in which is placed the substance whose dielectric constant is to be determined, consists of a small glass tube about 2 cm. in diameter and 4 cm. in length; within this a Pt. dish in the shape of a frustrum of a cone, which rests on the walls of the glass container; almost touching it is a perforated Pt. disc suspended from the top of the tube by a wire sealed through the glass, which serves as one of the leads. The arrangement is shown in Fig. 2. The tube is tubulated on both sides to allow for the introduction of the bromine vapor.

DETERMINATION OF THE CHANGE IN CAPACITY.

The tube V is set oscillating, the coils L_1 and L_2 and capacities C_1 and C_2 being so adjusted that the change in plate current with capacity is a maximum. The slope of this curve is a maximum in the neighborhood of the maximum current. The oscillations in the primary circuit are fed through the coil L^1 into the bridge. If the bridge is off balance, A and B will have a difference of potential, so that when the switch C is closed momentarily —the switch is open in the normal position—there will be a cur-

FIG. 2.



Condenser.

rent in the circuit containing the inductance L^2, which reacts on the plate circuit through the inductance L^3. This reaction will make a change in the plate current so that the potentiometer will be thrown off balance and the galvanometer, which is used to balance the potentiometer, will be deflected.

This action is the same as the regenerative action in detecting circuits and enables us to balance the bridge by a null method which is independent of the steadiness of the oscillator; and the visual method employed has also some advantages over the use of telephones. The bridge is adjusted until the momentary closing of the switch S produces no deflection of the galvanometer. The process is made easier in finding a rough adjustment by noting the difference between the right and left deflections of

the galvanometer, which depends on how the bridge is off balance. In order to get an accurate reading the condenser, which is worked from the outside, must always approach the balance from the same side, since the balance obtained from opposite sides disagrees by a small amount. This effect is present in any type of bridge oscillator.

After the potentiometer has been adjusted roughly, the circuit may be finely adjusted by the vernier C_1, which allows us to keep the spot of light on the scale if the primary circuit should change slightly.

When the bridge has once been balanced, the capacities C^1, C^3; C^4, and C^5 should be suitably changed until, upon successive rebalancings of the bridge, the variation of plate current with capacity C^6 is found to be a maximum. In this state the bridge is nearly in resonance with the primary circuit.

VARIATION OF DIELECTRIC CONSTANT WITH PRESSURE.

The bromine used in these experiments was purified by allowing it to stand for several days over P_2O_5 and then by introducing it into a vacuum system where it was frozen over liquid air while the air and other gases were pumped out. A given volume of this purified vapor at the pressure of 258 mm. of Hg was allowed to flow into the condenser system. This process was repeated until the bromine in the condenser reached the same vapor pressure as the vapor in equilibrium with the liquid, the dielectric constant being determined at each given step in the operation. The type of variation of the dielectric constant with the pressure of the bromine vapor are shown in Fig. 3. The nature of these curves (taken at 23.9° C.) is very similar to those obtained by C. F. Zahn for water vapor at room temperature. The dielectric constant K increases rapidly with the pressure to a value far above that calculated from the index of refraction or from the dielectric constant of liquid bromine using the relation

$$K - 1 = c.\ \rho$$

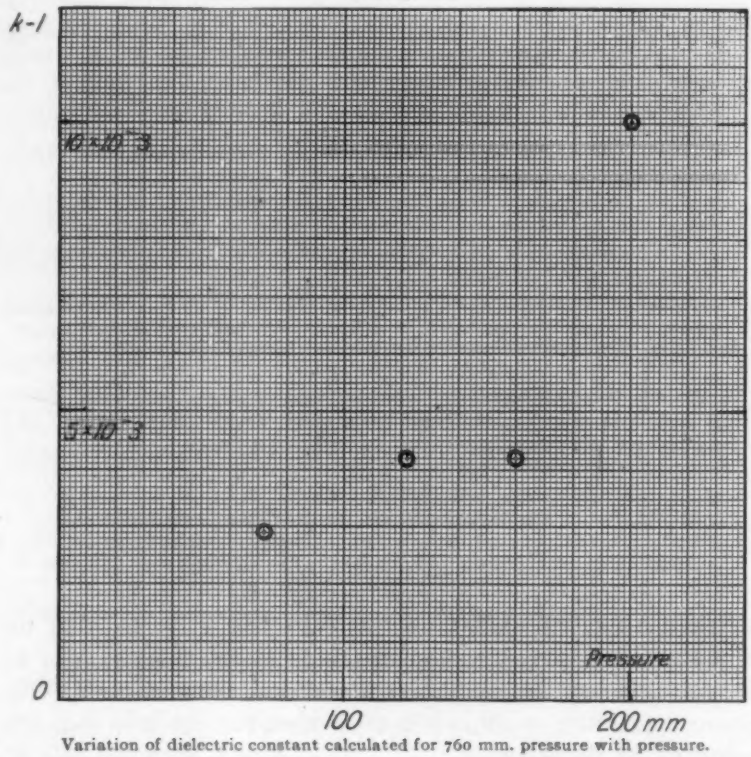
where

K = dielectric constant,
ρ = density,
c = constant.

The variation of the pressure of the bromine vapor with amount of gas introduced into the condenser system was measured by a diffusion device, shown in Fig. 4. A given volume of gas

at vapor pressure corresponding to room temperature was introduced into the pressure-gauge system, and the time the gas required to diffuse through the capillary A until the pressure in the discharge chamber B reached such a value that a high-voltage discharge passed between the electrodes, was recorded. The pressure was found to vary linearly with the amount of gas

FIG. 3.



Variation of dielectric constant calculated for 760 mm. pressure with pressure.

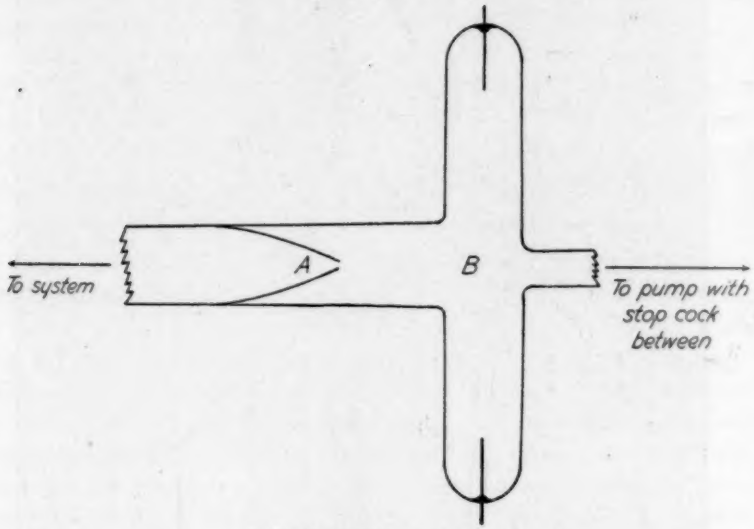
so that no association of bromine vapor under ordinary conditions was detected.

In order to test whether any association was caused by the electric field, a cell containing two parallel plane Pt. electrodes was placed in one arm of a Michelson interferometer. The bromine, which was solidified in a liquid-air trap attached to the cell, was allowed to melt and to vaporize until it came to equilibrium with the liquid at room temperature. The fringes were then observed

before and after a potential difference of 5000 volts was given to the plates, but no displacement of the fringes was observed. In this apparatus a fringe shift of .2 could have been detected.

These two experiments show that no association of bromine vapor can occur in the condenser during the course of the experiment when the pressure is varied. There are, however, two other possible ways of accounting for the abnormal behavior of the di-

FIG. 4.



Diffusion pressure gauge.

electric constant of vapors. C. T. Zahn has suggested that the abnormal behavior can be accounted for by the formation of an absorbed layer of the liquid on the plates of the condenser. The apparent dielectric constant $\bar{k}$ is then related to the true dielectric constant k by the relation

$$\bar{k} = k\left(1 + \frac{t}{d}\left(1 - \frac{k}{4}\right)\right)$$

where d = distance between plates

$\frac{1}{2}t$ = thickness of absorbed layer

and where the dielectric constant of liquid Br_2 has been taken as four.

Using the data found for Br,

$$\overline{k} = 1.0101$$
$$k = 1.0023$$
$$\frac{t}{d} = 1.41 \times 10^{-2}$$

from index of refraction.

Since in our experiment d was .1 cm., the thickness of the absorbed layer would have had to be 6.0×10^{-4} cm. From the measurements of surface films, it does not seem very probable that the absorbed layer could have such a large value as predicted from the observed results. In order to explain these abnormal effects we will, therefore, have to consider other factors which may have an influence on the value of the dielectric constant.

DIELECTRIC CONSTANT AND PROBABILITY OF TRANSITION.

The index of refraction n, according to the Lorentz-Kramer relation, is given for any wave-length λ by the relation

$$\frac{n^2 - 1}{n^2 + 2} = \alpha \sum_{s=1}^{\infty} \frac{\nu_s \lambda^2 \lambda^2 s}{\lambda^2 - \lambda^2 s}, \quad \alpha = \text{constant}$$

where ν_s depends on the probability Asp of a transition from some particular state s to any other state p, such that the line with the wave-length λsp is absorbed, the life of the electron in the state p is τsp and the total number of atoms in the state s is N_s.

$$\nu_s = NsAsp\tau sp .$$

As we allow λ to become infinitely great,

$$n^2 \longrightarrow k$$

i.e.,

$$\frac{k - 1}{k + 2} = \alpha \sum_{s=1}^{\infty} \sum_{p=1}^{\infty} NsAsp\tau sp\lambda s^2 p .$$

In order to examine more closely the relation between the index of refraction and the dielectric constant, we shall consider the case of a gas which has absorption lines $\lambda_1 p$, $\lambda_2 p$, ... $\lambda_n p$ in the infra-red and $\lambda_{n+1} p$ . . . . in the ultra-violet end of the spectrum, the lines being arranged in order of decreasing wave-length.

Then the index of refraction for a wave-length λ where $\lambda_n p > 10\lambda$ and $\lambda > \lambda_{n+1} p$ is given by

$$\frac{n^2 - 1}{n^2 + 2} = -\sum_{s=1}^{n} \sum_{p=1}^{\infty} \alpha N s \tau sp A sp \lambda^2$$
$$+ \sum_{s=n+1}^{\infty} \sum_{p=1}^{\infty} \alpha NsAsp\tau sp \left(\lambda^2 sp + \frac{\lambda^4 sp}{\lambda^2 - \lambda^2 sp} \right)$$

while the dielectric constant is given by the relation

$$\frac{k-1}{k+2} = \alpha \sum_{s=1}^{\infty} \sum_{p=1}^{\infty} NsAsp r_{sp} \lambda^2_{sp}.$$

In the formula for the index of refraction, the value of the first n terms, $s = 1 - - n$, is less than .01 of the corresponding terms in the relation for the dielectric constant, so that if these terms contribute an appreciable amount to the value of the dielectric constant, the index of refraction squared will not give an accurate estimate of the value of the latter.

We shall now attempt to calculate the way the probability of a transition depends on the temperature and pressure. Consider an enclosure at temperature T, containing a gas at pressure p. Let Nm be the number of atoms in the m^{th} state at the above conditions. In unit time a certain number of the atoms will pass from the s^{th} to the p^{th} state, absorbing energy of an amount $ch/\lambda sp$, where h is Planck's constant and c the velocity of light, due to the electric field. Let this number be $AspNs$, where Asp is the probability of a transition if the external field alone determined the number of transitions. In the enclosure, there will be, however, radiation of frequency $\nu(sp)$, of energy density $U\nu(sp)$. Under its influence atoms will pass from the s^{th} to the p^{th} state, the number in unit time being $U\nu(sp)BspNs$. The probability of a transition from the s^{th} to the p^{th} state is, therefore, $Asp + U\nu(sp)\,Bsp$. In equilibrium as many atoms will pass from the s^{th} to the p^{th} state as in the reverse direction, so that, if we designate the reverse transition by a reversal of the subscripts of the A's and B's

$$Ns\,(Asp + U_\nu\,(sp)\,Bsp) = Np\,(Nps + U_\nu\,(sp)\,Bsp).$$

Now by Boltzmann's relation

$$\frac{Ns}{Np} = \frac{p_s}{p_p}\, e^{\frac{\epsilon_p - \epsilon_s}{kT}} = \frac{p_s}{p_p}\, e^{\frac{h\nu\,(sp)}{kT}}$$

where p_s and p_p are the weights attached to the two different states, respectively.

The probability of an absorption transition becomes, therefore,

$$Asp + U_\nu\,(sp)\,Bsp = \frac{p_p}{p_s}\, e^{-\frac{h\nu\,(sp)}{kT}}\,(Aps + U_\nu\,(sp)\,Bps) \qquad (1)$$

where the A's and B's are constants independent of the external conditions only in case there is no external field applied.

If we write

$$Asp = asp$$
$$Aps = aps + \alpha ps$$

where asp and aps represent the parts of the probability functions due to the application of the external electric field. Now at low temperatures where the effect of radiant energy on the equilibrium is negligible, we must have a statistical equilibrium between the components of the probability due to the applied field, *i.e.*,

$$asp = \frac{p_p}{p_s} e^{-\frac{h\nu (sp)}{kT}} aps .$$

Since the a's must be of the same order of magnitude, we can take the a's to be of the following form

$$asp = A^p s e^{\frac{\varepsilon_s}{kT}}$$
$$aps = A^s p e^{\frac{\varepsilon_p}{kT}}$$

which gives

$$A^p s = \frac{p_p}{p_s} A^s p .$$

If we replace the Asp's in the above equation 1 by their value in terms of the constants $A^p s$, which are independent of the temperature, there results the familiar statistical equilibrium condition

$$\alpha^s{}_p p_p = U\nu \left(B^p s e^{\frac{h\nu}{kT}} - B^s p p_p \right)$$

which leads to Planck's law for the energy density.

We shall now carry out an analogous calculation in order to find how the life of the atom in the state s varies with the temperature, neglecting the influence of the energy density $U\nu$. The number of atoms in the state s, Ns is related to the life of the atom in that state τsp by the relation

$$N_s = \sum_{\substack{p=1 \\ p \neq s}}^{\infty} \left(A^p s e^{\frac{\varepsilon_p}{kT}} + \alpha sp \right) N p \tau sp$$

taking τsp independent of $U\nu$.

Then
$$\frac{N e^{-\frac{\varepsilon_s}{kT}}}{\sum_{n=1}^{\infty} e^{-\frac{\varepsilon_n}{kT}}} \cdot ps = \frac{\Sigma N \cdot p_p e^{-\frac{\varepsilon_p}{kT}}}{\Sigma e^{-\frac{\varepsilon_n}{kT}}} \left(A^p s e^{\frac{\varepsilon_p}{kT}} + \alpha sp \right) \tau sp$$

or
$$psε^{-\frac{ε_s}{kT}} = \Sigma_p p_p \left(A^p_{se} \frac{ε_p}{kT} + α_{sp} \right) e^{-\frac{ε_p}{kT}} τ_{sp}$$
$$= \Sigma_p p_p \left(A^p_s + α_{spε}^{-\frac{ε_p}{kT}} \right) τ_{sp}$$

which gives a solution of $τ_{sp}$ of the following form

$$τ_{sp} = \frac{t_{spε}^{-\frac{ε_s}{kT}}}{1 + α_{spε}^{-\frac{ε_p}{kT}}}$$

where t_{sp} and $α_{sp}$ are independent of the temperature.

If

$$α_{sp} << 1$$
$$τ_{sp} = t_{spε}^{-\frac{ε_s}{kT}}$$

while if

$$α_{sp} >> 1$$
$$τ_{sp} = \frac{t_{sp}}{α_{sp}} ε^{\frac{hν(sp)}{kT}}$$

an expression which probably represents the conditions better than the first.

The method of calculation, which we have used above, will only serve to give us an idea of the type of variations to be expected in the far infra-red region of the spectrum and will only be justified if the temperature variation of the dielectric constant comes from the variation in the terms due to the infra-red spectrum of the molecule; a condition, however, which is verified in the case of water vapor.

Returning now to the consideration of the Lorentz-Kramer expression for the dielectric constant, using the values of A_{sp} and $τ_{sp}$ which we have determined, we obtain an equation of the following form:

$$\frac{k-1}{k+2} = βp \sum_{s=1}^{\infty} \sum_{t=1}^{\infty} A^t_{se}^{\frac{hν(st)}{kT}} \frac{t_{st}}{α_{st}} λ^2_{st}$$

where $β$ = constant and p = pressure.

At high temperatures an equation of this form is practically independent of the temperature, but as we lower the temperature, the terms with low energies, *i.e.*, the ε's, start to increase and at a sufficiently low value of the temperature may preponderate over the other terms. The data obtained by Zahn for water vapor indicate that at room temperature one of the terms of the sequence

$$e^{\frac{h\nu}{kT}} A^{l}s \frac{tst}{\sigma st} \lambda^{2}st$$

becomes greater than the sum of all the other terms of the series. Moreover, the temperature variation of the above form predicts fairly accurately the behavior of the dielectric constant valuation with temperature.

CONCLUSIONS.

The theory outlined above indicates that the change of the dielectric constant of Br_2 and HOH from the values predicted by the index of refraction is due to the temperature variation of the probabilities of an absorption transition in an external electric field for the energy states of the atom, or molecule, which give the infra-red spectra of the vapor. The variation of the dielectric constant of Br_2 with pressure gives an abnormal increase far above the value we would expect, but no trace of association was found on measuring the pressure against volume or in the presence of a high electric field.

REFERENCES.

[1] ZAHN, C. T.: *Phy. Rev.*, March, 1926.
[2] BRAMLEY, A.: *Phy. Rev.*, June, 1925.

Celebration of the Centenary of the Invention of Photography.—Reference was made in a lecture before The Franklin Institute by Dr. Henry Leffmann, which appeared in this JOURNAL (**195**, p. 327, 1923) to the intention of French photographers to celebrate in 1923 a photographic centenary. Inasmuch as Daguerre's methods were not made known until 1839, it seemed that the celebration was premature, but the fact is that the first actual picture-making by light with a camera is claimed for Nicéphore Niépce, who obtained in 1822 a picture with the aid of bitumen of Judea which becomes insoluble in some solvents when exposed to the light. Niépce coated a metal plate with the bitumen, exposed it to an illuminated image and the bitumen underwent changes in proportion to the light falling on it. The unchanged portions were then washed off and the metal etched. The whole coating was then removed and

a plate was obtained from which prints could be made. It is said that the procedure was quite successful, artistic effects being obtained. The story is related at a meeting of the French Society of Photography and published in the Bulletin of the Society ([3], 1925, 12, 221). The account is followed by a brief summary of some of the more striking advances in photography since Niépce and Daguerre. It appears from this summary that little progress was made except by French investigators. No mention is made of the introduction of the dry plate nor of Muybridge's studies of motion, nor of the German workers. The invention of the motion picture is ascribed definitely to the Brothers Lumière. Such neglect of work in other nations is not fair, but it is rather characteristic of some French scientists.

Niépce seems to deserve the credit of initiative in an entirely different field. He has been shown to have been the inventor of an internal explosion motor. In 1806, he, with his brother, took out a patent for an explosion motor in which finely powdered materials (lycopodium and powdered charcoal with resin) were used. The work was not appreciated and the machine was forgotten. The descriptions have been found and in March of last year a communication was presented to the Academy of Sciences in Paris stating that a motor constructed as indicated had been successfully operated by experts connected with aeronautic service. H. L.

Absolute Determinations of the Wave-lengths of X-rays by Means of a Glass Grating. (*Comptes Rendus,* Jan. 4, 1926.)—A beam of X-rays from a copper anti-cathode after passing through two narrow slits falls at almost a grazing angle upon a glass grating with 200 rulings per mm. A photographic plate, located so as to catch the light reflected from the grating, shows (*a*) an impression produced by the direct rays that have failed to be intercepted by the grating; (*b*) an impression caused by rays totally reflected from the glass, and (*c*) a series of lines forming a spectrum containing not only separate lines, but different orders of these lines. These lines are very clear in outline. Their intensity is augmented by the total reflection of the incident light. They are due to diffraction. "By illuminating the grating under a very small angle the difference in the optical paths of two waves reflected by adjacent elements of the grating may become very small and under these conditions diffraction of the X-rays ought to be observed." From measurements made on the positions of the first and second orders of the $K\alpha$ line its wave-length was calculated to be 1.540 Å.U., correct to 1 per cent. From measurements made on crystals the value 1.538 was obtained.

Thus the reflection grating can be used to get the wave-length of X-rays as well as of visible light. Incidentally the agreement of the two results given above furnishes a confirmation of the accepted values of the distances between the planes of the crystals employed.

G. F. S.

ULTRA-MICROMETER CIRCUITS.*

BY

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PRECISE measurements are of fundamental importance in industry as well as in pure science. Any device capable of measuring a physical quantity to a higher precision than has been hitherto attainable opens up a new field for investigation and development in which unexpectedly important facts may be discovered. For this reason new and delicate methods of measurement such as are now and then developed in laboratory practice deserve the careful study of practical and experimental workers alike in order that, through an exact understanding of them, suitable applications may promptly be made and the advances inherent in these applications be taken advantage of at the earliest possible time.

The simplest physical measurement is that of length. Lengths have been measured from the earliest times by the direct application of a "standard scale" by which method we may with proper precautions attain a certainty in end-reading of 1/10 of a millimetre or of 1/100 of an inch. The precision of such measurements was long ago increased by the application of verniers to the scales and by the use of micrometric screws. Finely cut micrometer screws with properly graduated heads can now be purchased to read to 1/10,000 of an inch or to 1/1000 of a millimetre. In ordinary use, however, the micrometer screw is generally used to read to 1/1000 of an inch and 1/100 of a millimetre. The figures just quoted give an idea of the limits of precision in measurements by straight mechanical methods. For those tests where a notably higher precision is necessary, as in the study of small strains and distortions, optical methods have been employed. Of these the most delicate are those employing some form of interferometer where the interference pattern produced by light properly reflected between two parallel plates can be made to shift in a measurable way by relative motions of the two plates of the fraction of one wave-length of the light employed. In this

* Presented at a meeting held Thursday, November 12, 1925.

way a movement of the order of ten one-millionth of a centimetre may be measured. This limit of measurement, which is, of course, 1/10,000 of a millimetre, indicates that a higher order of precision can be attained by the interferometer method than by straight mechanical means.

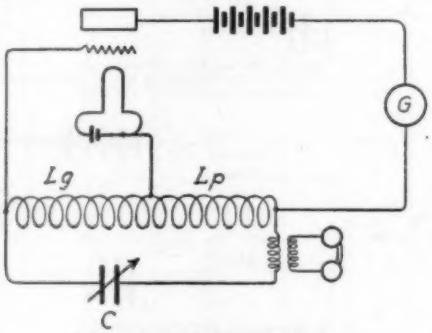
There are, however, many tests which could be made more definite and many measurements which could be better carried out if still smaller displacements could be read with certainty. Fortunately, the extensive experiments which have been carried out in recent years with vacuum-tube circuits have uncovered certain interesting electrical methods for measuring displacements in which the limit of delicacy of interferometer methods has been surpassed by a factor of 10 or 100. Some experimenters claim to have measured by these new methods down to the hundred millionth of an inch, about equal to the diameter of a single atom of hydrogen. It is certainly easily possible to make consistent measurements to the millionth of an inch or to the millionth of a centimetre with such circuits. Arrangements of this kind are called *ultra-micrometer circuits*. Since they are the latest development in the science of exact measurement, they deserve careful study.

The first of the ultra-micrometer circuits was described in 1920 by Professor Whiddington,[1] of the University of Leeds. Since that date numerous modifications of the Whiddington circuits have been employed without the introduction of any essentially new ideas. The Whiddington ultra-micrometer is frequently called the heterodyne beat ultra-micrometer, a name descriptive of its mode of operation, as we shall shortly see. In 1922 Dowling,[2] of the University of Dublin, described in detail for the first time an ultra-micrometer circuit differing from that of Whiddington and called generally the zero shunt ultra-micrometer. All electrical ultra-micrometers in use at the present time can be classified as belonging to one of the two types above mentioned. In a study of these circuits it is best to give attention first to the Dowling type, which is considerably more simple than Whiddington's in construction if not in operation. The Dowling ultra-micrometer consists essentially of an oscillating vacuum-tube circuit containing suitable recording instruments. Oscillating tubes are also involved in the Whiddington instrument. Our subject can therefore be well introduced through a brief consideration

of the nature and diversity of the oscillation circuits which may be applied in work of this sort.

Fig. 1 represents a typical oscillating-tube circuit. The plate, filament and grid of the tube are hooked up so that an inductive coupling exists between the plate and grid circuits—between the coils L_p and L_g. If this coupling has a proper value, and if certain other conditions relating to the constants of the tube and its attached circuits are met, then an electrical oscillation will begin

FIG. 1.



Typical oscillating circuit (Hartley).

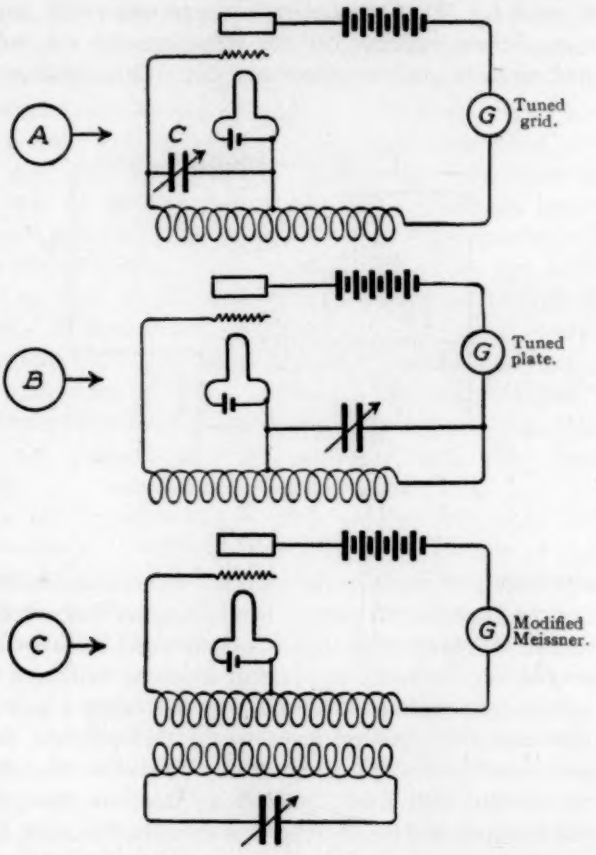
$$f = \frac{1}{2\pi\sqrt{LC}}$$

to surge back and forth in the loop LC as soon as the filament circuit is closed and the filament is brought to its correct temperature. In practice, no great difficulty is experienced in throwing circuits into oscillation. Almost any circuit made of ordinary radio parts in which a condenser is involved, together with a pair of coils in the plate and grid circuits, respectively, will produce more or less energetic and persistent oscillation. It is usually much more difficult to eliminate such oscillations than to start them. The particular circuit shown in Fig. 1 is frequently called the Hartley circuit. If the circuit parts were arranged in any one of the ways shown in Fig. 2, or in any of a variety of other ways not shown, oscillation would still take place. Fig. 2*A* is called a "tuned grid" circuit, the name being derived from the position of the condenser across the grid inductance. Fig. 2*B* is a "tuned plate" or Colpitt's circuit, and Fig. 2*C*, where the oscillation loop is separated from the tube circuit proper, is a modified Meissner circuit. These circuits are all popular and efficient oscillating

arrangements and have all been used in one development or another of the ultra-micrometer.

The oscillations in these circuits, consisting as they do of a surging of electrons through the inductance and into and out of

FIG. 2.

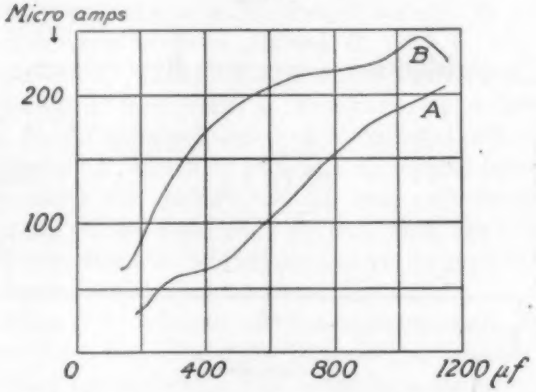


Various types of oscillating circuits.

the condenser, have a definite natural frequency which can be calculated from the capacity of the condenser C and the inductance of the coil L by the well-known formula $f = \frac{1}{2\pi\sqrt{LC}}$ if the capacity is expressed in farads and the inductance in henries. In using this formula the effect on the frequency of the resistances in the circuit is neglected, but this is justifiable in practice.

Let us select the circuit Fig. 2*A*—the tuned grid circuit—for more detailed consideration. A certain definite direct current is flowing in the plate circuit during operation, on which the alternating current of the oscillations will be superposed whenever the tube starts into oscillation. The strength of the direct current in the plate circuit may be shown by the reading of the galvanometer or milliameter at *G*. Now it has been found that the strength of the direct component of the plate current in such a

FIG. 3.

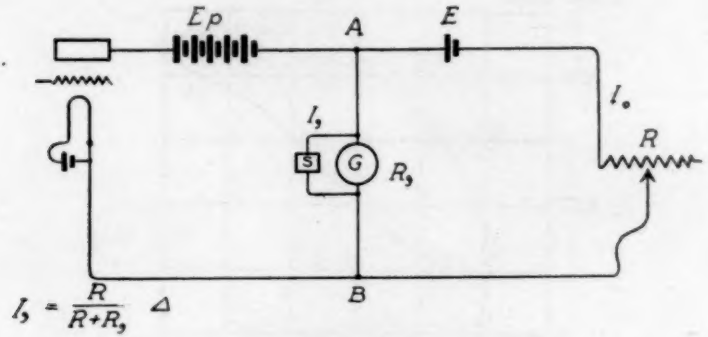


Variation in current through *G* with change in capacity *C*.

circuit as this varies with the frequency of the oscillations. In other words, if the coil, *L*, be of fixed inductance, then the reading of the galvanometer, *G*, will be found to alter with any variation in the capacity of the condenser, *C*. We shall not enter into an explanation of the precise causes of this variation. The character of the variation as experimentally determined for two different adjustments of a tuned grid circuit is, however, clearly shown in Fig. 3. It is seen that in the case of curve *A* the relation between the change in the galvanometer reading and the capacity change causing it is almost exactly linear over a considerable range. Curve *B*, made with a different grid-plate coupling, is much less regular. It is a general fact that selection of a proper coupling in a circuit of this character enables the experimenter to produce a substantially straight characteristic as shown at *A*. Such an adjustment is naturally very desirable if the circuit is to be used, as it obviously may be used, for measuring capacity changes in the condenser through observation of the galvanometer

readings. Since very sensitive galvanometers are readily obtained, it is evident that extremely minute capacity changes corresponding to very small movements of the condenser plates can be thus measured or, at any rate, detected. The total capacity change shown in Fig. 3 (1000 micromicrofarads), which produced a change of over 200 micro-amperes in the plate current, is about the same as would be produced by turning the knob of an ordinary 42-plate radio air condenser through 180 degrees. This, however, by no

FIG. 4.



The zero shunt.

means represents the most sensitive adjustment of such a circuit.

The relation plotted in Fig. 3 is the one made use of in Dowling's ultra-micrometer. A moment's consideration will show, however, that an important modification of some kind must be made in circuit *2A* before the data for Fig. 3 can be obtained from it. The normal plate current through *G* with *C* fixed in value is of the order of one milliampere—the variations in this current caused by changing *C* by a small amount are of the order of one micro-ampere. If, therefore, *G* is reading on its scale for the initial value of *C*, the change in reading due to small alterations in *C* will be entirely imperceptible. What is needed at *G* is evidently an instrument which will show minute variations in the plate current without responding to the normal value of the current itself. Dowling devised a circuit arrangement equivalent to such an instrument and thus produced a practical ultra-micrometer. Dowling called his circuit arrangement a "zero shunt."

The details of the zero shunt are shown in Fig. 4. At *G* we

have a galvanometer with a protective shunt. The full sensitivity of this galvanometer need in no case be greater than 10^{-8} amperes. It is evident that no current can flow through G when the points A and B are at the same potential. In the branch A-R-B we have at E a rise in potential due to the small battery there shown (one or two storage cells) and at R a fall of potential, when the circuit is in operation, due to the RI drop in the adjustable high resistance R. If this RI drop, which can be brought to any selected value for a fixed I by altering R, be adjusted until it is exactly equal to the potential rise at E, then there will be no resultant potential difference between A and B, and G will therefore remain undeflected. This zero adjustment is, however, only good for a fixed value of the current I. If I increases or decreases ever so slightly, the RI drop will increase or decrease to a value different from that of E, which is supposed to remain invariable, and the galvanometer will deflect. If the zero adjustment be made for the normal value of the plate current, then the galvanometer will follow alterations in the current and yet be undeflected by the normal current—which was the condition sought.

Since when G is deflected the plate current is obviously dividing between the G branch and the R branch, it becomes important to enquire how far the readings of G can be taken to represent the entire variation in plate current. It is evidently this entire variation which is most simply related to the capacity changes as represented in Fig. 3. This point can be settled by an application of the most elementary formulas. Let i be the normal current for which the galvanometer is balanced and i_g and i_o the current through G and R, respectively, when the circuit is unbalanced. Let Δ represent the small change in the plate current. Now $E = Ri$ when the circuit is balanced. When it is not balanced,

$$i + \Delta = i_g + i_o$$

and

$$i_g R_g = Ri_o - E.$$

From these equations

$$R\Delta = Ri_g + Ri_o - Ri$$

and

$$R\Delta = Ri_g + R_g i_g,$$

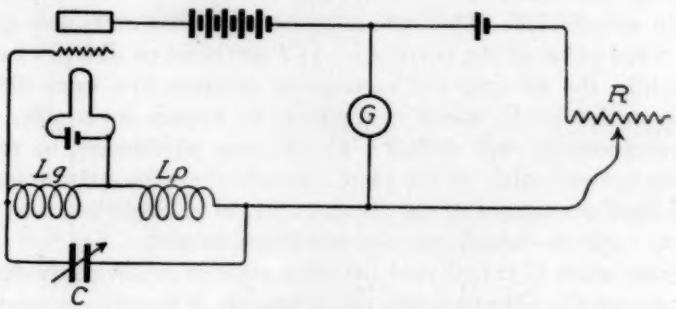
whence,

$$i_g = \frac{R}{R + R_g}\Delta.$$

This final equation shows that i_g, the current through the galvanometer when unbalanced, may be taken to equal the entire change in plate current, Δ, if R is sufficiently large compared with R_g. This condition is easily met in practice since R may readily be made one hundred times as great as the galvanometer resistance.

When a galvanometer with a zero shunt is inserted in the plate circuit of an oscillating tube, we have a complete Dowling ultra-micrometer. Any type of oscillating circuit may be used. In Fig. 5 we have represented a complete ultra-micrometer, using

FIG. 5.



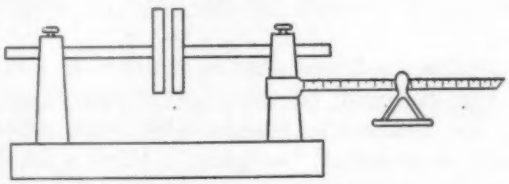
The Hartley ultra-micrometer.

a Hartley circuit. The coils L_p and L_g are flat wound, about four inches in diameter, consisting of about 150 turns of No. 28 enamelled wire, set coaxially and adjustable in coupling by moving along their axes. A suitable separation for these coils is about one-half inch. C is an adjustable air condenser with a maximum capacity of 1200 micromicrofarads. The galvanometer, G, is sensitive to 10^{-8} amperes. R is a dial box resistance adjustable by tenths of ohms up to 1100 ohms. This arrangement can be made to give a linear variation of current with capacity between condenser settings of 100 and 1000 micromicrofarads. The rate of change, in a particular case, was 10 micro-amperes per micromicrofarads. This meant that, using the galvanometer at its full sensitivity, a change in capacity of one micromicrofarad in the condenser caused a galvanometer deflection of 1000 scale divisions or, conversely, a deflection of one scale division indicated a capacity change of one one-thousandth of a micromicrofarad.

This minimum measurable capacity change, if produced in a

parallel plate condenser of two plates by moving the plates apart, corresponds to an exceedingly minute relative movement. Let the plates be 10 centimetres in diameter and one-quarter of a millimetre apart, then it can readily be shown that a capacity change of one micromicrofarad will result from a plate movement of one ten-thousandth of a centimetre. If now a condenser (Fig. 6) of this description be inserted in place of C (Fig. 5), a galvanometer deflection of one scale division, indicating, as stated above, a capacity change of one one-thousandth of a micromicrofarad,

FIG. 6.



Special steel plate test condenser.

will indicate a relative movement of the plates of one ten-millionth of a centimetre. The circuit is thus seen to be capable of measuring small displacements to 10^{-7} centimetre.

Since the capacity of the pair of parallel plates is represented by the well-known formula $C = KA/4\pi D$ (where A is the area of one plate, D is the distance between the two plates and K is the dielectric constant), an exceedingly minute change in the dielectric constant of the material separating the condenser plates will, on the other hand, suffice to produce the minimum capacity change perceptible in this circuit, so that we have here a very sensitive means for detecting alterations in dielectric constants. Although the application of these methods to dielectric constants is not strictly a "micrometric" one, it represents an important development to which attention must be given. Carman and Lorance,[3] for instance, have described experiments using the Dowling circuit in which the dielectric constants of various gases were determined, the capacity changes being read easily to 1/100 of a micromicrofarad.

We shall now mention certain of the practical uses to which this circuit of Dowling's has been put. Dowling himself [2] measured strains in metal bars involving displacements of 10^{-7} cm. in devices which were essentially extensimeters. Such devices

have an obvious importance in engineering laboratories since by their use the initial stages of rupture or of permanent deformation may be studied more closely than has been done heretofore. He has also attached one plate of his variable condenser to the diaphragm of a pressure gage, being thus enabled to obtain a continuous record of pressure change over any desired range depending on the stiffness of the diaphragm. He obtained in one case reading to one-third of one-millionth of an atmosphere corresponding to 0.32 dyne per square centimetre. Such an arrangement applied to a mercury manometer ought to show variations in pressure of the order of one-millionth of a millimetre.

If the movable condenser plate be attached to a balance beam, the circuit can evidently be used for ordinary weighings and particularly for comparing masses which are supposed to be identical, such as standard "weights." With a fixed weight on the beam, studies of variations in the force of gravity at different places may be made or measurements of the gravitational pull of small masses placed adjacent to the fixed weight may be carried out. In this way Dowling measured the pull of a 50-kilogram mass of lead at a distance of 25 cm. from his fixed weight of one kilogram. Another interesting application has been to the study of the growth of root tips of plants, where a growth over five ten-thousandths of a centimetre in fifteen minutes has been followed closely enough to show the recurrent "growth pulses" described by Bose.

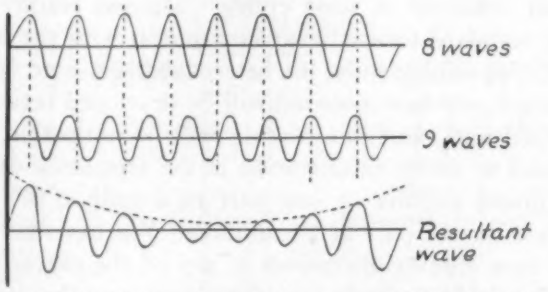
Another use of great engineering importance has been in the investigation of out-of-balance forces in rotating machinery. If this work is being carried out on a rotating armature or on a turbine motor, the end of the shaft and its surrounding bearing may be taken as the test condenser since the film of lubricating oil serves to hold these surfaces out of contact at all times.

In contemplating the application of ultra-micrometer circuits to uses such as have just been enumerated, it is well to know that certain practical difficulties always arise, such that each new use constitutes in a sense a research problem in itself. These difficulties are connected with drifting of the zero point of the galvanometer, with inductive disturbances due to adjacent conductors or to the body of the observer and with the selection of a proper coil design and coupling to give a linear characteristic

over the desired range when the peculiarities of the special condenser used are considered. Industry, skill and an understanding of the underlying principles will, however, enable the experimenter to overcome all of these difficulties.

Let us now turn to ultra-micrometers of the first class mentioned at the beginning of this paper, namely, the Whiddington heterodyne beat pattern. In these instruments two oscillating circuits of nearly the same frequency are linked together in such

FIG. 7.



The principle of beat production between waves of different lengths.

a way that a "beat note" is produced between the two fundamental oscillations. The frequency of this beat note is equal to the difference of the frequencies of the two circuits. The production of a beat note in this way is referred to in the radio art as "heterodyning"—whence the name given the circuit. We need not enter here into any explanation of the principle of beat-note production. The phenomenon in electrical circuits is the same as in beat production between two sound waves, an alternate suppression and reënforcement of energy resulting from the interference of two wave-trains which differ in wave-length. As shown in Fig. 7, the number of reënforcements, of "beats," per second is equal to the difference in the number of waves given off in each second from the two different sources. If one electric circuit is producing 1,000,000 oscillations per second and the other 1,001,000, oscillations, a beat frequency of 1000 will be developed. If telephones are properly connected into either of the circuits the beat tone only will be heard, since frequencies of the order of a million cannot pass through the impedance of the phones and would in any case be incapable of producing an audible sound.

Since the pitch of the beat note as determined by its fre-

quency is given by subtracting the frequency of the one circuit from that of the other, it is evident that a change in the second circuit from a frequency of 1,001,000 to 1,001,001—namely, of one part in a million—will be reflected by a change in the beat note from a frequency of 1000 to a frequency of 1001.

It is probable that no human ear could distinguish the slight change in pitch associated with this frequency alteration of one cycle. Whiddington, however, rendered such small changes easily apparent by using for comparison a second audible tone maintained definitely at 1000 cycles. The ear readily perceives when this standard tone is in precise unison with the heterodyne beat note. If, subsequently, the heterodyne beat note varies from 1000 to 1001, one beat a second will be developed between it and the standard note, and this beating will be noticeable. We are thus enabled to detect an alteration in the frequency of either of the two linked circuits of one part in a million or, at higher frequencies, of one part in ten million. We can thus detect, at the same time, minute alterations in any of the characteristics of the circuit which determine its frequency, namely, its capacity, inductance or resistance. If the resistance be neglected and the inductance be held constant, as is usually the case, the capacity changes dependent on movements of the condenser plates or on variation of the dielectric constant may be studied just as we have already described for the Dowling instrument.

Fig. 8 shows a pair of tuned grid circuits hooked up as a Whiddington ultra-micrometer. At P is shown the test condenser, the variations of the capacity of which as conditioned by movements of one of its plates are to be studied. The capacity of this condenser is given, as we have already stated, by the formula $C = KA/4\pi D$. The frequency of the circuit is given by

$$f = \frac{1}{2\pi\sqrt{LC}}.$$

From these formulas we may write

$$f = \left(\frac{D}{\pi LA}\right)^{\frac{1}{2}}.$$

Differentiation gives

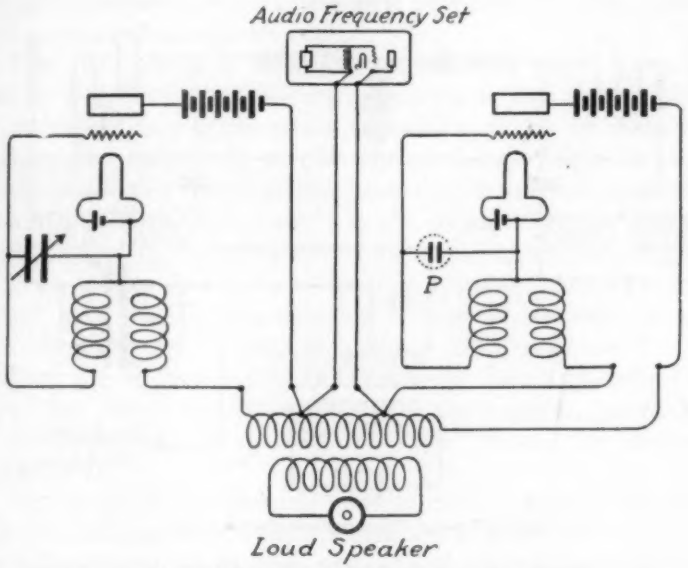
$$\frac{df}{dD} = \frac{1}{2(\pi LAD)^{\frac{1}{2}}} = \frac{f}{2D}.$$

If, now, f, the frequency, is one million (10^6) and D, the distance between the plates, is one-tenth of a millimetre (10^{-2} cm.).

$$\frac{df}{dD} = \frac{10^6}{2 \times 10^{-2}} = \frac{10^8}{2}.$$

If df is *one*, that is, if the frequency changes by one oscillation, a change readily detected since one beat per second is thereby produced between the heterodyne note and the standard note, then

FIG. 8.



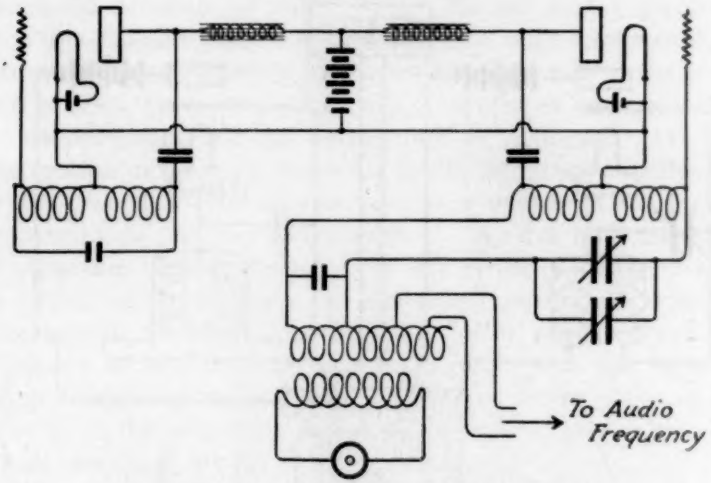
Whiddington ultra-micrometer circuit.

dD must be 2×10^{-8} cm. This calculation shows that, under properly controlled conditions, displacements of 10^{-8} cm.—the diameter roughly of a hydrogen atom—can be detected and measured with the Whiddington ultra-micrometer.

A variety of arrangements of circuit parts is of course possible in making up Whiddington circuits in practice. A sufficient linkage of the two oscillating circuits may be obtained merely by setting them up near each other or, better, a definitely adjustable coupling may be used between coils in the two plate circuits or in the grid circuits. The heterodyne note may be produced from a radio loud-speaker connected with an audio-amplifier in one of the plate circuits. The third circuit used to produce the

standard note may be set up with an independent loud-speaker, the beats used in measurement being then produced in the air, or the third circuit may be connected to the loud-speaker in the second oscillating circuit. Fig. 9 shows a circuit arrangement which has been found practical and compact.[9] Here, as in Fig. 8, the plate circuits of the three circuits are connected to the primary of a single transformer. The beat note between the standard and the output of the heterodyne is taken from the secondary. The

FIG. 9.



Practical form of Whiddington ultra-micrometer.

choke coils and by-pass condensers are introduced to render the use of a single high-tension battery possible.

The constants of the parts of these circuits must generally be altered to fit the particular problem, but parts roughly very like those described for the Dowling apparatus can be used. The circuit for producing the standard note must, because of its low natural frequency (about 1000), have relatively large inductances and capacities, as can be seen from a simple application of the fundamental formula $f = \frac{1}{2\pi\sqrt{LC}}$. A mica condenser, one microfarad by tenths, is useful in this connection.

The most delicate way to use this apparatus is to adjust the circuits to give 5, 10 or 15 steady beats in 5, 10 or more seconds, then to perform the desired operation on the condenser—for

instance, subject the supports (Fig. 6) to a strain of some sort—and redetermine the number of beats. From the indicated frequency change in circuit 2 it is of course possible to figure out the plate displacement, but in practice, due to distributed capacities and other influences which cannot be allowed for, this solution by calculation is not possible and the instrument must always be calibrated in some way before the results can be interpreted. A second method of use in which the original beat note is restored through manipulation of a standard condenser suitably inserted in the circuit also suggests itself.

The Whiddington ultra-micrometer has been applied to straight micrometer condensers measuring to one three-millionth of an inch [1]; to a temperature measuring device or mechanical thermometer measuring to one sixteen-thousandth of a degree Centigrade [4]; to a microbalance measuring to one ten-millionth of a load of a tenth of a gram [5]; to the measurement of dielectric constants and to the variation of these constants with temperature [6, 7]; to the detections of minute slipping in metals under stress [8]; to a study of the variation of dielectric constant of gases with magnetic field [9]; and to various other purposes.[10, 11] A study of the original literature bearing on these applications will show that many further applications are possible, particularly in investigational work and in close testing of materials or machinery.

For precise investigational work where a minute displacement or a small change in a dielectric constant is being looked for, the Whiddington circuit is more precise and more delicate than the Dowling. Where, on the other hand, a continuous record of a variation is desired, the Dowling circuits must be used. For an extended series of measurements the Dowling circuit is also to be recommended, since the ear soon tires and becomes uncertain in judging beat notes over too long a period of time. This last-mentioned disadvantage of the Whiddington circuits can be overcome at the expense of an increase in complexity by receiving the heterodyne and standard notes (set at a definite ratio) on a mirror device which projects a Lissajou figure on a screen. Slight changes in frequency ratio are then apparent to the eye. In practice, difficulty is found with this method of obtaining sufficiently steady figures for accurate work. The Dowling circuit in a form sufficiently delicate to measure displacements of the

order of a millionth of an inch can be easily assembled in any laboratory, the parts being few in number and usual in character. Once assembled, it can be kept in adjustment for nearly immediate use if first-class fresh storage cells are employed for the plate and zero shunt batteries. It thus has application as a routine laboratory device. The Whiddington circuits, on the other hand, are more highly sensitive to disturbing influence from a variety of sources, so that the use of them to any degree of precision demands extended preparatory adjustment and the steady attention of a skilled experimenter.

In conclusion, the author wishes to state that this paper was prepared originally for a lecture in which various applications of the circuits above described were actually demonstrated. In its present form the paper is perhaps useful in drawing attention to the possibilities of ultra-micrometers and in collecting a number of important references to the original contributions in this field.

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The Hottest Place (on Earth).—A French writer has recently given in the *Annales de Geographie* an account of the Death Valley in Southwest California as the greatest depression in any part of the United States, having a mean depth of about 270 feet below sea-level. This is, indeed, shallow as compared with the Dead Sea, the surface of which is nearly 1300 feet below the level of the Mediterranean. On the other hand, Death Valley appears to show the highest temperature yet recorded in any spot on the surface of the earth. A meteorologic station established in 1911 has numerous records of temperatures much above 100° F. and on July 10, 1913, 145° was noted. The valley is bordered by ranges, one of which has a maximum height of nearly 11,000 feet. It is worthy of note that the highest point in the United States is less than eighty miles away from the valley, Mount Whitney being about 14,500 feet above sea-level.

H. L.

THE ACTION OF RADIATION ON FREE ELECTRONS.*

BY

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BARTOL RESEARCH FOUNDATION
Communication No. 4.

MANY years ago Sir J. J. Thomson suggested that it would be interesting to see if a beam of electromagnetic radiation produced an observable effect upon a stream of electrons. The idea in mind no doubt was that the experiment might throw light on a fundamental problem of the physicist, the interaction of radiation and matter. Electrons were perhaps thought of because they were the lightest particles known and therefore would be affected by the radiation to a greater extent than heavier particles such as atoms or molecules. The experiment has been attempted a number of times, always with a negative result when clouds of electrons artificially produced in a vacuum were employed. Only when electrons in very great density were used, as in a gas at atmospheric pressure, the electrons being those in the atoms of the gas, and were exposed to short wave-length radiations as X-rays, did affects appear which could be attributed to the direct action of the radiation on the electrons.

The experiment was proposed in the days when the classical wave theory of light held sway. With the advent of the quantum concept of radiation a new interest arose in the experiment and in the underlying ideas. These have been discussed in two recent papers.[1, 2] The present paper treats the problem in more detail and presents theoretical calculations for the momentum transferred to the electrons by the radiation from a classical and quantum viewpoint. Briefly, the difference between the two theories is this: On the wave theory each electron will be moved about by the electric and magnetic fields of the light wave. Reactions due to radiation of energy from the electron will of course modify its motion, and the electron will thereby acquire momentum from the light. On the quantum theory the radiation is conceived

* Presented Wednesday, March 17, 1926.

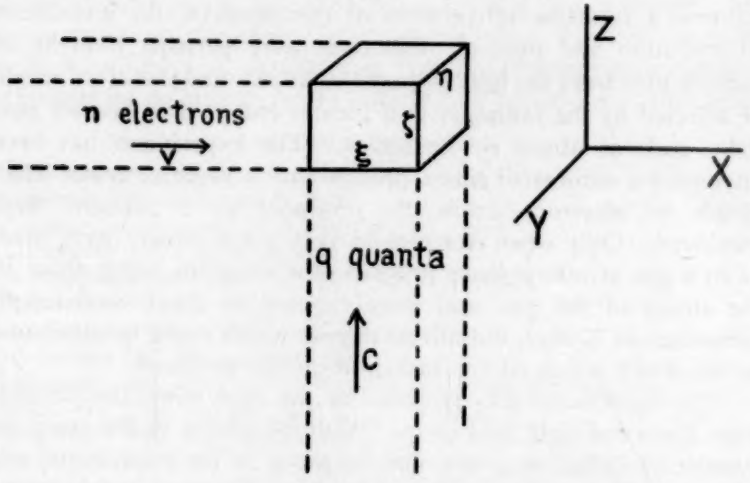
[1] HULBURT, *Phys. Rev.*, **21**, 650 (1923).

[2] HULBURT and BREIT, *Phys. Rev.*, **25**, 193 (1925).

to be made up of little pellets of energy, known as quanta, light darts, needle quanta, etc. (Curiously enough no direct mention need be made of the electric and magnetic fields of the quanta.) When the radiation passes through the cloud of electrons, a few of the electrons will receive violent impacts from the quanta, just as an army of men under a hail of bullets, and will possibly receive a large amount of momentum, whereas the remaining electrons which have escaped collision with the quanta will receive none at all.

Classical Theory.—We shall imagine a rectangular portion of space of dimensions ξ, η and ζ cm., through which pass a stream

FIG. 1.



of electrons and a beam of electromagnetic radiation in the manner indicated in Fig. 1. Let the velocity of the electrons be v in the direction of X, and of the radiation be C, in the direction of Z.

The action of light on the electron is derived very simply from the classical scattering theory of J. J. Thomson.[3] The electron under the influence of the electric and magnetic fields of the radiation experiences an acceleration. When the velocity of an electron is changed, radiation proceeds from the electron. This is the scattered radiation and its magnitude is proportional to the acceleration of the electron. When the primary radiation ceases,

[3] THOMSON, "Conduction of Electricity through Gases," p. 323, 2nd Ed. (1906).

the scattered radiation vanishes. Therefore in order to emit the scattered radiation the electron must have absorbed energy from the primary radiation exactly equal to the amount which it has radiated. The absorption of this energy produces a reaction on the electron which may be put in terms of momentum transferred to the electron from the radiation. We express these ideas in mathematical language following Thomson (*loc. cit.*).

If the energy densities in ergs/cm.^{3} of the primary and scattered radiations are E and S, respectively, then

$$S = 8\pi E e^4 \Delta t / 3m^2c^3, \qquad (1)$$

where Δt seconds is the time which the electron spends in the radiation. e is the electronic charge in c.g.s. electrostatic units and m is the mass of the electron. The momentum [4] transferred to the electron when it absorbs an amount of energy S is the momentum of a mass S/c^2 moving with the velocity c, which is S/c. The momentum acquired by the electron may be written $m\Delta v$, where Δv is the change in velocity experienced by the electron in time Δt. Therefore

$$\begin{aligned} m\Delta v &= S/c, \\ &= 8\pi e^4 E \Delta t / 3m^2c^4, \\ &= 8\pi e^4 E \xi / 3m^2c^4 v, \end{aligned}$$

since, from Fig. 1, $\Delta t = \xi/v$. The original momentum of the electron is mv. Hence

$$\frac{\Delta v}{v} = \frac{8\pi}{3} \frac{e^4 E}{m^2c^4} \frac{\xi}{v^2}. \qquad (2)$$

This ratio of the change in velocity divided by the primary velocity of the electron, which is of course also the ratio of the acquired momentum to the original momentum, is the desired expression for the effect of the radiation on the electron stream derived from the classical wave theory.

Quantum Theory.—The quantum calculation is a statistical one and involves two steps, the determination of the number of collisions per second of the quanta with the electrons and the determination of the amount of momentum transferred from the colliding quantum to the electron. We adopt an extreme point of view and consider the quantum to be endowed with momentum

[4] See, for example, Sommerfeld, "Atomic Structure and Spectral Lines," p. 259 (1922).

and a "diameter." Referring to Fig. 1, let the number of electrons per c.c. in the electron stream be n and the number of quanta in the radiation beam be q. Denote the diameters of the electron and quantum by σ_e and σ_q, respectively. The mean free path f of the quantum in the electron stream is assumed to be that calculated from the kinetic theory of gases. The mean free path[5] of a particle of diameter σ_q which moves among the electrons with the same velocity as the average electronic velocity is $1/\sqrt{2}\pi n(\sigma_e+\sigma_q)^2$. But the quanta move with a velocity very great compared with the average velocity of the electrons, so that the latter may be considered to be at rest. Maxwell[6] has shown that the free path of a particle moving through a collection of spheres at rest is $\sqrt{2}$ times the free path if the spheres were moving with an average velocity equal to that of the moving particle. It follows that

$$f = 1/\pi n(\sigma_e+\sigma_q)^2. \tag{3}$$

If a quantum moves a distance ζ through the electron stream the probability of its colliding with an electron is ζ/f. Across the area $\xi\eta$ (Fig. 1), there pass $q\xi\eta c$ quanta per second. Therefore in the space $\xi\eta\zeta$ the probability each second for a collision between a quantum and an electron is

$$qc\xi\eta\zeta/f. \tag{4}$$

In other words, expression (4) is the number of collisions per second in the rectangular space. Since every collision produces a change in the velocity of the electron, (4) gives the number of electrons which are diverted per second.

The number of electrons which pass through the space $\xi\eta\zeta$ each second is $n\eta\zeta v$. Therefore the original momentum of these is this number multiplied by mv, which is

$$mv^2n\eta\zeta. \tag{5}$$

No further advance is possible in the quantum aspects of the problem without a statement as to the effect on the electron of collision with a quantum. This is supplied from the quantum theory of scattering of X-rays of A. H. Compton.[7] By means of

[5] JEANS, "The Dynamical Theory of Gases," p. 32 (1904).
[6] MAXWELL, "Collected Papers," 1, p. 386.
[7] COMPTON, *Phys. Rev.*, 21, 482 (1923).

this theory the kinetic energy K of the recoil electron ejected at an angle θ with the incident quantum ray was calculated [8] to be

$$K = \frac{2\alpha h\nu \cos^2\theta}{(1+\alpha)^2 - \alpha^2\cos^2\theta}, \tag{6}$$

where

$$\alpha = h\nu/mc^2.$$

ν is the frequency of the radiation and h is the action constant of quantum theory. The momentum p of the electron corresponding to the kinetic energy K is

$$p = mc\left\{\frac{2K}{mc^2} + \left(\frac{K}{mc^2}\right)^2\right\}^{\frac{1}{2}}. \tag{7}$$

This equation is obtained by eliminating $\beta = v/c$ from the two equations of relativistic mechanics

$$\left.\begin{aligned} p &= m\beta c(1-\beta^2)^{-\frac{1}{2}}, \\ \text{and} \quad K &= mc^2[(1-\beta^2)^{-\frac{1}{2}} - 1]. \end{aligned}\right\} \tag{8}$$

Substituting (6) in (7) yields

$$p = 2mc\alpha(1+\alpha)\cos\theta \cdot /[(1+\alpha)^2 - \alpha^2\cos^2\theta]. \tag{9}$$

Since no reason can be given why larger or smaller angles of recoil should predominate, the probability of an electron recoiling at an angle θ may be taken to be constant for all values of θ between $-\pi/2$ and $+\pi/2$. With this assumption the average value of p over all angles becomes

$$\bar{p} = \frac{1}{\pi}\int_{-\pi/2}^{+\pi/2} p\,d\theta. \tag{10}$$

Introducing into (10), the value of p from (9), there results after some reduction

$$\bar{p} = \frac{4h\nu}{\pi c}\,\frac{1+\alpha}{\alpha\sqrt{1+2\alpha}}\sin^{-1}\frac{\alpha}{1+\alpha}. \tag{11}$$

From equations (4) and (11), the momentum acquired per second by the electron stream from the beam of radiation is $qc\xi\eta\zeta\bar{p}/f$. The original momentum is given by (5). Therefore $\Delta v/v$, the ratio of the acquired momentum to the original momentum is

$$\Delta v/v = qc\bar{p}\xi/fmnv^2.$$

[8] COMPTON and HUBBARD, *Phys. Rev.*, **23**, 439 (1924).

Introducing the value of f from (3), we have

$$\frac{\Delta v}{v} = \frac{\pi q c \bar{p}}{m} (\sigma_e + \sigma_q)^2 \frac{\xi}{v^2}. \tag{12}$$

This is the quantum expression which corresponds to the classical expression.

Long Wave-lengths.—In the case of radiation of wave-lengths longer than 0.01 Å., α is small compared with unity and equation (11) assumes a simpler form. Actually α is of the order 10^{-2} for X-rays of wave-length 1 Å. and of unit order for γ-rays of wave-length 0.01 Å. When α is small compared with unity, (11) reduces approximately to $\bar{p} = 4h\nu/\pi c$. Equation (12) then becomes

$$\frac{\Delta v}{v} = \frac{4qh\nu}{m} (\sigma_e + \sigma_q)^2 \frac{\xi}{v^2}. \tag{13}$$

We note that $\Delta v/v$ is proportional to the frequency ν.

Application of the Correspondence Principle.—According to the Principle of Correspondence equation (2), based on classical theory, may be identified with the quantum theory equation (13) for the longer wave-lengths. This principle has been given many forms, both special and general. The form which, perhaps, envisages most directly the present problem is, "the unknown statistics of the individual quantum events are actually furnished by the classical calculation."[9] In the present case the statistics of the quantum events are known, under the specified assumptions. So that the Correspondence Principle may be called upon to determine the diameter of the quantum σ_q which is unknown. In the quantum equation (13) we substitute for m the classical value[10] $4e^2/3c^2\sigma_e$ and for $qh\nu$ the obvious value E. We obtain

$$\frac{\Delta v}{v} = \frac{8}{3\pi} \left(\frac{\sigma_e + \sigma_q}{\sigma_e} \right)^2 \times \frac{8\pi}{3} \frac{e^4 E}{m^3 c^4} \frac{\xi}{v^2}.$$

Identifying this with (2), results in

$$\frac{8}{3\pi} \left(\frac{\sigma_e + \sigma_q}{\sigma_e} \right)^2 = 1 \tag{14}$$

This is the relation which must be satisfied if the classical and quantum expressions are to be identical for the longer wave-lengths. It follows that the diameter of the quantum is small compared with that of the electron; from (14) σ_q is about a

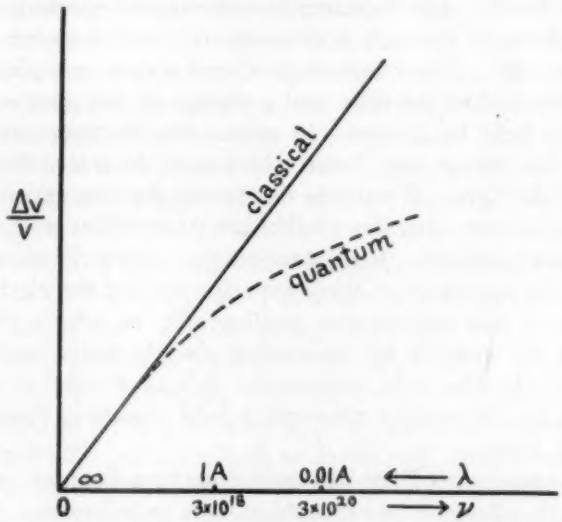
[9] SOMMERFELD, *Loc. cit.*, p. 584.

[10] THOMSON, *Loc. cit.*, p. 652.

tenth of σ_e. It should perhaps be pointed out that equating the classical and quantum expressions for the total scattered energy involves the identity of the spatial distribution of the scattered energy on the two theories. It may be emphasized that the diameter of the quantum which has emerged is a kinetic theory diameter, and perhaps has as much meaning as the diameter of any particle, as a molecule, derived from kinetic theory considerations.

Very Short Wave-lengths.—For wave-lengths below 0.01 Å., and hence for values of α greater than unity, the quantum equation

FIG. 2.



(12) shows that $\Delta v/v$ increases with ν more slowly than if a linear relation existed. So that for the very short wave-lengths the quantum expression predicts less total momentum transferred to the electrons than does the classical expression. These facts are illustrated by the curves of Fig. 2. The region of wave-lengths in which the two theories differ appreciably is that below 0.01 Å., which is none too easy of access, and it would appear therefore difficult to distinguish between the two theories by a direct experiment.

Experiments.—H. A. Wilson attempted to observe a change in a stream of electrons caused by a beam of condensed sunlight. The results were not published, but Professor Wilson has kindly stated in a letter that the experiment indicated that the radiation

probably produced no noticeable action on the electrons. In a glass bulb highly evacuated electrons from a hot filament were drawn by a positive potential to two collecting plates placed close to each other, side by side, in the far end of the bulb. The electron currents to each plate formed the arms of a very sensitive Wheatstone bridge. With the bridge balanced, an intense beam of light was played upon the electron streams, but no disturbance of the bridge was observed attributable to the direct action of the light on the electrons. Recently C. J. Lapp [11] has carried out a similar experiment and obtained what we regard as a similar negative result. The experiment consisted of sending a narrow ray of electrons through a distance of about a metre along an exhausted tube. The electrons produced a spot on a photographic plate at the end of the tube, and a change in this spot was looked for when light or X-rays fell across the electron ray near its source. No change was found which could be traced to the direct action of the light. It must be mentioned that the experiment is a very troublesome one, the elimination of spurious and secondary effects being difficult. It is interesting to notice the close analogy between the apparatus of these experiments and the electron tubes of radio or the cathode-ray oscillograph, in which streams of electrons are swayed by alternating electric fields impressed on the tube. In the light experiment it was sought to sway the electrons by the rapidly alternating field, speaking classically, of the light itself.

The equations of the foregoing paragraphs may be used to estimate the effects to be expected in these experiments. Considering the energy density of the X-radiation from a Coolidge tube, the energy of the cathode rays in the tube under normal operation is about 200 watts. According to R. T. Beatty [12] perhaps the fraction 5×10^{-4} of the cathode-ray energy goes into the general X-ray spectrum. If the characteristic radiation of the target is excited, a larger fraction of the energy passes into the emitted X-rays. The X-ray beam from the Coolidge tube of course diverges, but let us assume that all the X-ray energy is confined to a beam of a uniform cross-section of 1 cm.^{2}. The energy density of the X-radiation is then 3×10^{-5} ergs/cm.^{3}. For sunlight, taking the solar constant to be 0.042 calorie per cm.^{2} per

[11] LAPP, *Phys. Rev.*, **20**, 104 (1922).
[12] BEATTY, *Proc. Roy. Soc.*, 89A, 314 (1913).

sec., the energy density is 5×10^{-5} ergs/cm.^{3}, which may be increased say a hundred-fold to 10^{-3} by a lens. Rough calculations for the powerful 20-kilowatt searchlight with reflector give about the same energy density as the condensed sunlight.

With the low value of 10^8 cm./sec. for v, the velocity of the electrons, and with $\xi = 100$ cm., which are very favorable conditions, and with $E = 10^{-3}$ ergs/cm.^{3}, the classical equation (2) gives $\Delta v/v = 10^{-14}$. This is a small quantity far below the limits of observation. To detect this Wilson would have had to observe a change in his electric currents of one part in 10^{14} and Lapp a shift or an enlargement in his spot of 10^{-14} cm.

From a quantum standpoint we may say that although a collision between a quantum and an electron may impart a great enough velocity to the electron, the collisions are so few as to be below detection in the type of experiment just mentioned. To put this in more detail, we may suppose that the electron stream, of cross-section 1 cm.^{2} and of velocity 10^8 cm./sec. carries a current of 1 ampere. Then $n = 10^{11}$; and in the X-ray beam $q = 10^3$, if E is 3×10^{-5} and the average wave-length is 1 Å. Taking $\sigma_e = 10^{-13}$ and $\sigma_q = 10^{-14}$ cm. the number of collisions per cm.^{3} per sec. is 10^{-1}, as determined from (4). This is a small number when compared with the large numbers of electrons and quanta engaged. Enlarging the scale until the electrons are the size of ducks and the quanta as large as golf balls, the case is to be compared with pelting a flock of ducks, each duck being 200,000 miles from its neighbor, with a hail of golf balls, each ball being 200,000,000 miles from the next. It is small wonder that so few hits occur. In the atmospheres of the stars where the radiation may be intense and the density of electrons very great, the pressure of the radiation on the electrons may be very important.

In a very beautiful experiment, C. T. R. Wilson [13] and Bothe [14] were able to observe the direct action of the radiation on the electrons. The experiment consisted of sending a pulse of X-radiation through moist air at approximately atmospheric pressure. Just before the pulse of radiation was released the air was subjected to a sudden small expansion, so that the water vapor present was on the point of condensing. Those electrons which were struck by a quantum were ejected out of their parent

[13] WILSON, *Proc. Roy. Soc.*, **104**, 1 (1923).
[14] BOTHE, *Zeits. f. Phys.*, **16**, 319 (1923).

atoms with sufficient velocity to produce a small cloud of ions. The water vapor promptly condensed on this cloud to form a drop of water, which because of its shape was called a "fish track." The drop was illuminated by a spark and photographed. The whole process from the expansion of the air to the photography of the water drop took place in a small fraction of a second. The photographs showed that the number of fish tracks per cm.^{3} was of unit order, indicating roughly one collision per cm.^{3} between the quanta and the electrons in the time during which the radiation lasted. This is to be expected from (4). For, with $q = 10$, which appears reasonable for the X-ray beam employed, and with $n = 10^{20}$ for the electrons in oxygen or nitrogen at atmospheric pressure, (4) gives a probability of 10^6 collisions per cm.^{3} per sec. Since, however, the electrons are not uniformly distributed, but are grouped in the atoms, this probability must be reduced by a factor equal to the square of the ratio of the atomic diameter to the distance between the atoms, or $(10^{-8}/10^{-6})^2 = 10^{-4}$. This gives 10^2 for the probability. The pulses of X-radiation were only about 10^{-2} sec. in length, so that the probability finally becomes unity, in agreement with the experimental observation.

Essentially, the positive results of the cloud-drop experiment, as contrasted with the negative results of the other experiments, are to be attributed to the employment of large numbers of electrons, so that the chances of collision with quanta were appreciable, and to the experimental method whereby the effects of the separate collisions were rendered visible. Furthermore, the cloud-drop experiment demonstrated that the momentum from the radiation was transferred vigorously to a relatively few electrons, the other electrons being disturbed to a much less extent or not at all. This is in keeping with the ideas of quanta and is contrary to a simple wave theory. It should be pointed out, however, that the foregoing wave-theory treatment, although adequate perhaps for considerations of the total momentum, does not suffice for the calculations of the effect of the waves on the individual electrons. A complete discussion of these details on the wave theory is not attempted here, for it would lead far beyond the confines of the present paper into the fluctuation theory of Einstein and Smoluchowski.[15]

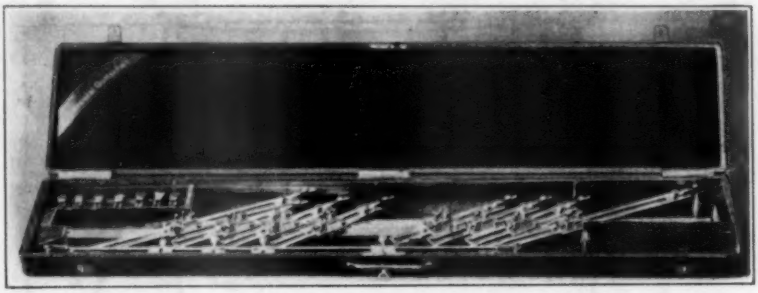
[15] EINSTEIN, *Phys. Zeit.*, 10, 189 (1909); see also PERRIN, "Atoms," Chap. V.

MECHANICAL CALCULATION OF ELASTIC SYSTEMS.

BY

OTTO GOTTSCHALK, C.E.

STATICS generally has been treated as a mathematical science, expressing in abstract and complicated formulæ and equations, the behavior of forces and works which act on different structures, employing such formulæ with purely mathematical procedures, and finally interpreting, in terms of resistance, the results thus obtained. However, it is possible to eliminate all these accustomed complications, which obscure rather than clarify the



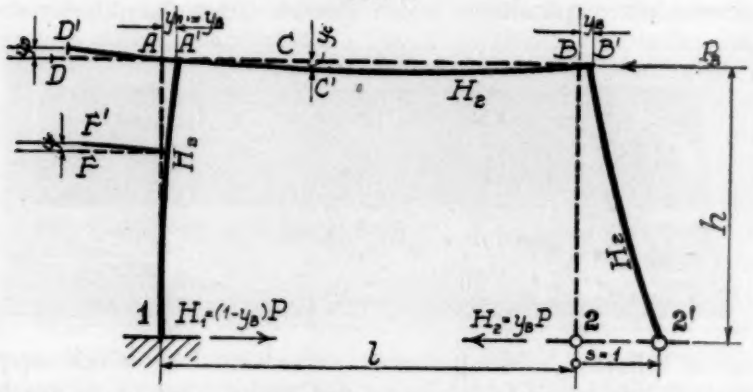
statical behavior, working directly with elastic lines which correspond to the forces to be determined, making use of an appropriate machine.

It is with this proposal that the author has invented the "Continostat Gottschalk" with which he has been able to find out methods described in this article and which permits automatically and instantaneously the determination of the conditions and exigencies of resistance of any structure. Surely no professional man, however well grounded in analytical geometry, would use circular equations or tables each time that he needs a circular arc when there is a compass at hand. In the same way it is not logical to analyze with formulæ, with great sacrifice of time and mental exertion, elastic behavior, if with one movement we can produce it in the same plan of the structure. This has been the work of many engineers for some time and attempts in technical literature have not been lacking, but so far there does not appear to have been any great result in practical application.

I ought to mention, as interesting contributions, the work of D. B. Steinman, of New York, who, in his article, "Influence Lines as Deflection Diagrams," [1] explains the modern conception of influence lines, and of George Erle Beggs, of Princeton, who, in his article, "Mechanical Determination of Forces in Complicated Constructions," [2] describes many examples of deformation of models of cardboard or celluloid, reading with the microscope the displacements, determining the forces on the basis of Maxwell's theorem.

Using the methods explained in this article, the task of calculating elastic systems, however complicated, is reduced to obtain-

FIG. 1.



ing instantly elastic lines by means of the above-mentioned "Continostat," reading at sight the ordinates at the sections where the exterior forces act and multiplying these ordinates by the respective force. Thus, in a few minutes problems of statical calculations of structures are solved, which with the accustomed mathematical methods take hours and days of intense work subjected to innumerable errors.

1. INFLUENCE LINES.

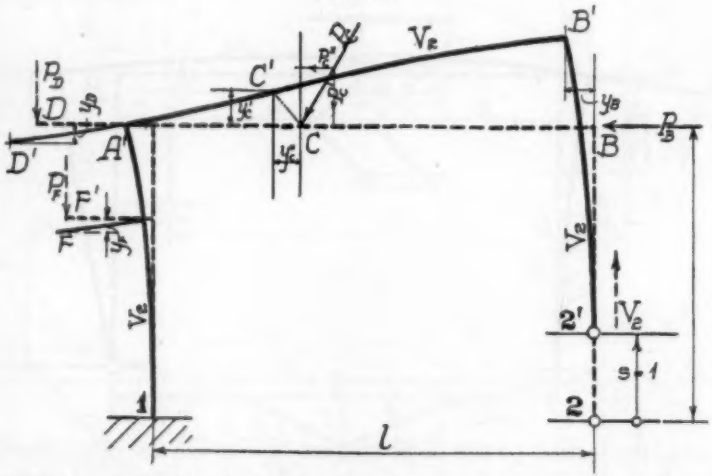
Let us consider, for example, the portal of two columns, indicated by dotted lines in Fig. 1, the base 2 of the right column is free to move, the base 1 is fixed. Let us displace 2 to 2′ through a very small horizontal space s, deforming the portal as indicated by the full line and displacing the sections ABC to $A'B'C'$. These

[1] *Engr. Record*, Nov. 25, 1916.
[2] *Internat. Engineering*, May, 1922.

small movements have vertical and horizontal projections y_A, y_B, y_C, as the case may be.

Let us suppose now that a load P, which produces the work $P_C y_C$ in moving the support 2 through s, acts on C; if no other load acts to produce internal work since s is small, equilibrium of the work exists: $H_2 s = P_C y_C$, that is, $H_2 = P_C \frac{y_C}{s}$, if we let $s = 1$ we shall have $H_2 \times 1 = P_C y_C$. In a similar way $H \times 1 = P_B y_B$ when P_B alone acts. That is to say, making $s = 1$, the portal forms the influence line for the horizontal reaction H_2. The author after many experiments has been able to prove that these relations, which

FIG. 2.

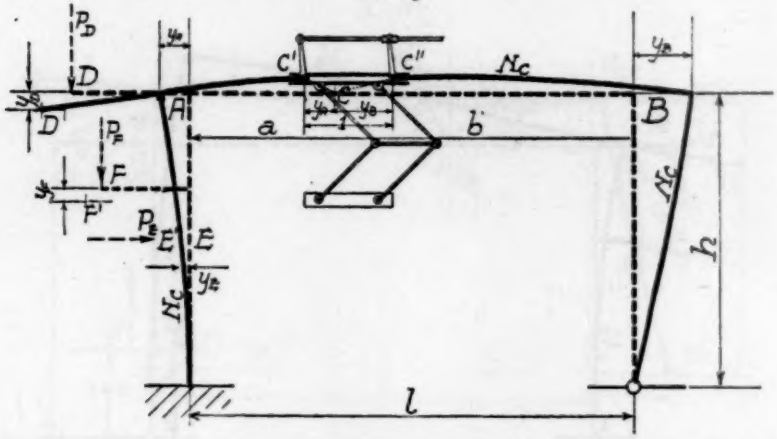


are correct for virtual displacements, are also correct with sufficient approximation, within certain limits, for movements quite visible and measurable, using models made of steel splines of great elasticity and flexibility. It is this experiment which permits the elimination of all formulæ. The calculation of elastic systems is thus reduced to the drawing of elastic influence lines, and the reading of the axial and transversal displacement which the point, where a force acts, suffers and multiplying by the intensity of such force. Raising the support 2 through $s = 1$ as per Fig. 2, we obtain automatically the influence line of the vertical reaction V_2. Thus a load P_D on D produces a vertical reaction $V_2 = P_D \frac{y_D}{s}$ and a horizontal force in $BV_2 = P_B \frac{y_B}{s}$.

On the other hand, an inclined force P_C on the point C, whose vertical and horizontal components are P'_C and P''_C, respectively, will produce a reaction $V_2 = P'_C y'_C = P''_C y''_C$, y'_C and y''_C being the vertical and horizontal projections, respectively, of the displacement of the point C.

Cutting the beam AB at C and separating, as per Fig. 3, through $s=1$, the adjacent sections C' and C'' in an axial direction, avoiding all transverse and turning movement, the elastic portal forms the influence line for the normal forces at C. A vertical load P_F on F produces at C a tension $N_C = P_F y_F$; y_F being the

FIG. 3.



vertical projection of the displacement of F. On the other hand, a horizontal force P_E produces a compression in C; $N_C = P_E \frac{y_E}{s}$.

Cutting the beam AB at C as per Fig. 4, and separating through $s=1$, the adjacent sections C' and C'' in a transverse direction, avoiding all axial and turning movement of C' with respect to C'', the elastic portal forms the influence line of the shear at C.

Cutting the beam AB at C as per Fig. 5 and revolving through $s=1$, the two adjacent sections C' and C'', one with respect to the other, however, restraining all transverse and axial separation of the same; that is, supposing a pivot at C, the elastic portal forms the influence lines of the bending moments at C, y_B being, for example, the horizontal displacement of the point B, which corresponds to the rotation 1; the horizontal force P_B at B will produce at C a bending moment $M_C = P_B y_B$.

2. IMPORTANT PROPERTIES OF INFLUENCE LINES.

Considering the influence lines as elastic lines of an elastic beam AB of uniform section, whose ends have rotated through

FIG. 4.

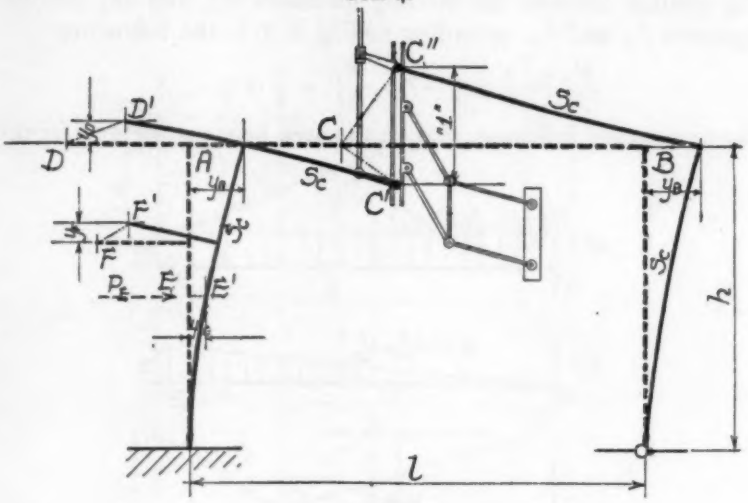
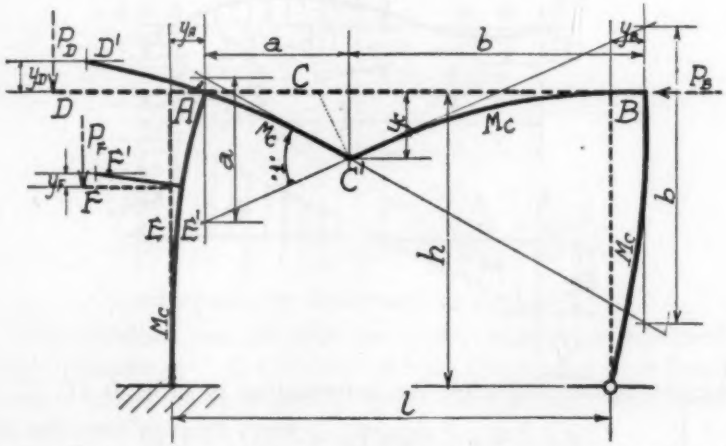


FIG. 5.



any angle, as a function of the segments f_A and f_B (Fig. 6), which the tangents drawn through A and B determine with the vertical through the centre of AB. The equation results,

$$y = 2\frac{x}{l} f_A = \frac{2x^2}{l^2}(2f_A - f_B) - 2\frac{x^3}{l^3}(f_B - f_A)$$

For $x = \frac{1}{2} l$, $y = h$ or the height of the curve at the centre

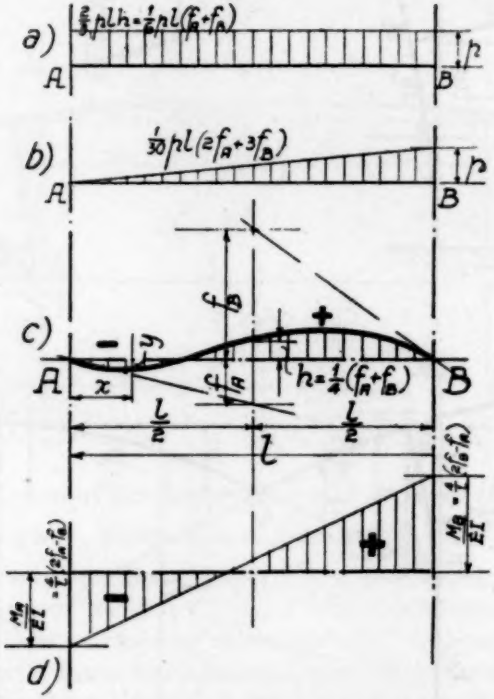
$$h = \frac{1}{4} (f_A + f_B)$$

The relation between the bending moments M_A and M_B and the segments f_A and f_B, according to Fig. 6 *d*, is the following:

$$\frac{M_A}{EI} = \frac{4}{l^2} (2 f_A - f_B), \quad \frac{M_B}{EI} = \frac{4}{l^2} (2 f_B - f_A)$$

The area of the influence, that is, the area between the axis of the

FIG. 6.



structure before and after the deformation is (Fig. 6 *a*)

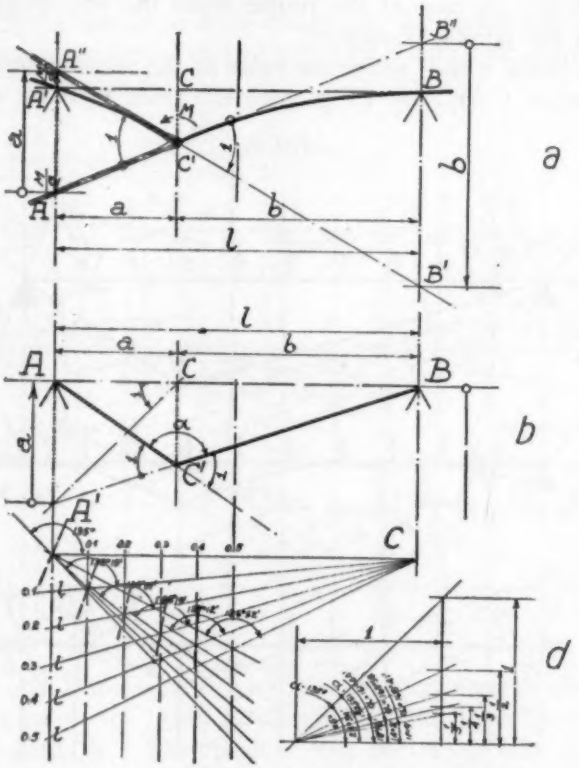
$$F = \frac{2}{3} hl = \frac{l}{6} (f_A + f_B) = \frac{l}{30} (5 f_A + 5 f_B)$$

The same modified area with ordinates $y \frac{x}{l}$ corresponding to a uniform increasing load, increasing from o in A to p at B is

$$F_1 = \frac{l}{30} (2 f_A + 3 f_B)$$

These simple mathematical expressions, determined by the author for the area of the influence in beams or other members of structures of uniform section, is true not only for the total length, but also for any part and any length and direction of f_A and f_B.

FIG. 7.



3. TRIGONOMETRIC RELATIONS OF ROTATION "1".

Loads which can act upon an elastic system as indicated in Fig. 5 produce at C, at a distance a from the support A, a bending moment M, which on its part produces the work $M \times 1$ in rotating the adjacent sections from C through 1.

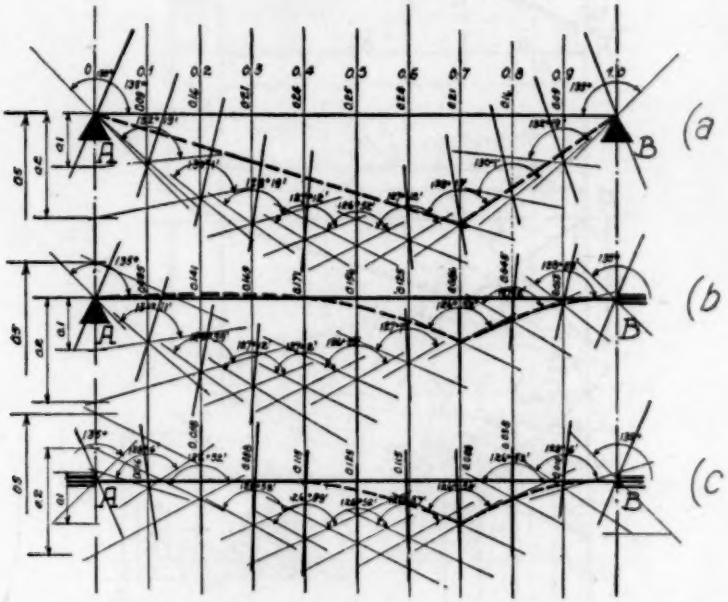
Let us suppose that this work is caused by two levers fixed on the beam on each side of C, respectively, and that they coincide with the axis of the beam AB in its original position. At the end of the rotation 1 the levers will have the position indicated in Fig. 7 *a*, after having moved vertically for the support A the dis-

tance Y. The force which had to act vertically at each instant is $\frac{M}{a}$, which in moving a causes the work $\frac{M}{a}y$.

There exists equality of works $M \times 1 - \frac{M}{a}y$, or $y - a$, the segment which the levers or the tangents determine vertically through A. In case of the simple beam the two tangents pass through the points of support.

The limits within which the value of the angle complement of the rotation 1 can vary (Fig. 7 *c*) are from 116° 52′ when the

FIG. 8.



bisector of α is perpendicular to the beam AB and 135° when the bisector of α has its maximum inclination. For this last case it is convenient at times to know the angles which correspond to the fractions 1/2, 1/3, etc., of the rotation 1, whose values are indicated in Fig. 7 *d*.

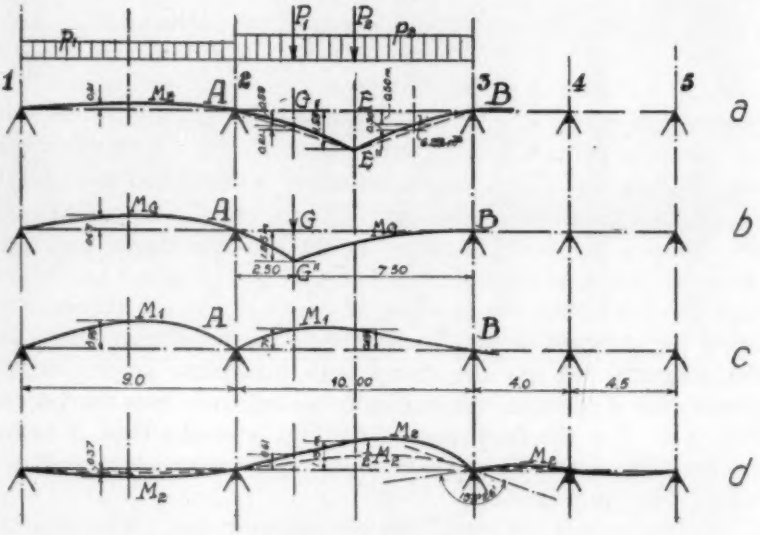
Fig. 8 has been prepared to demonstrate the value of the angle of rotation α in various sections of beams simply supported, and with one or two ends fixed.

Accordingly it can be noted that the difference between the maximum angle α, which is produced at the end, and the minimum

at the centre of the beams is only 6.5 per cent.; while it is interesting to observe that granting an allowance of 1 per cent., the angle α at the middle of the simple beam can be considered constant (Fig. 8 *a*) from $a = 1/5$ to $a = 9/10$, that is, approximately, $7/10l$ for the beam fixed at B (Fig. 8 *b*) and 13/15 for the beam fixed at A and B as per Fig. 8 *c*.

Taking advantage of these conditions, the author has invented broken beams composed of two pieces of elastic steel spline which,

FIG. 9.



by means of a special influence and bending moment clamp, are held together at the break in the angle α and form the influence line automatically. The result is that the clamp with minimum angle serves with sufficient correctness for almost the whole length of the beam, and another clamp, used when the angle is maximum, embraces, for all practical purposes, all problems which present themselves in rectilinear systems.

4. THE CONTINUOUS BEAM.

The case of statically indeterminate systems which presents itself more often in the life of the engineer is the continuous beam, which will be treated in the first place.

(1) Let us take a continuous beam of four unequal spans

(Fig. 9), loaded with uniform and concentrated loads, whose bending moments in various sections are required.

With this object we place the movable scale of the "Continostat" over points of support in the plan and pass through these points a broken steel spline with a clamp called No. 2. To calculate the bending moments at E, we place the clamp below E (Fig. 9 *a*), forming automatically the influence line of M_E. We read off or mark the ordinates at the sections where the forces act. Thus a concentrated load $P_2 = 10\ t$ at E produces a bending moment, $M_E = 1.59\ m \times 10\ t = 15.9\ tm$. On the other hand, $P_1 = 5\ t$, which acts at G, produces at E the moment $M_G = 5.0 \times 0.59 = 2.95\ tm$. The influence line M_G determines between A and B an area $F = 10.00 \times 1.59 \times \frac{1}{2} - \frac{2}{3} \times 5.00 \times 0.21 - \frac{2}{3} \times 5.00 \times 0.30 = 6.25\ m^2$; then acting from A to B, a uniform load of 3.00 t/m gives a bending moment at E, $M_E = 6.25\ m^2 \times 3.00\ tm^{-1} = 18.75\ tm$. This simple procedure is illustrated in Fig. 10. If we want the bending moments M_G at G we slip the spline until the clamp is below G, marking on the plan the elastic line thus obtained, which is the influence line for M_G (Fig. 9 *b*). At the load $P = 5.0\ t$ then the moment $M_G = 5.0 \times 1.25 = 6.25\ tm$, 1.25 being the ordinate at G. To determine the bending moments at the supports, we use the clamp with maximum angles, which placed over A produces automatically the influence lines marked on Fig. 9 *c*. For the loads shown on Fig. 9 results then, p being 2.0 t/m, $M_A = 0.71\ P_1 + 0.69\ P_2 + \frac{2}{3} \times 9.0 \times 0.99_{P_1} + \frac{2}{3} \times 10.0 \times 0.69_{P_2} = 20.99\ t/m$.

In Fig. 10 *c* is illustrated this last influence line. The moment M_B is obtained as per Fig. 9 *d;* to avoid disproportionate forces in the steel ribbons we generally use at the supports clamp No. 3, which correspond to the rotation ½ only, and consequently it is necessary to multiply the ordinates thus obtained by 2.

(2) To ascertain the shearing forces in any part of the continuous beam recently treated, let us suppose transversal resistance is eliminated, separating through (1) the ends of the cut steel spline, however, preventing all relative axial and circular displacement. In Fig. 11 is indicated the position assumed, which on the "Continostat" permits us to obtain instantly the influence line of the shear for any point of the beam.

The reactions are obtained automatically, displacing the support whose reaction is required. Displacing the second support

FIG. 10.

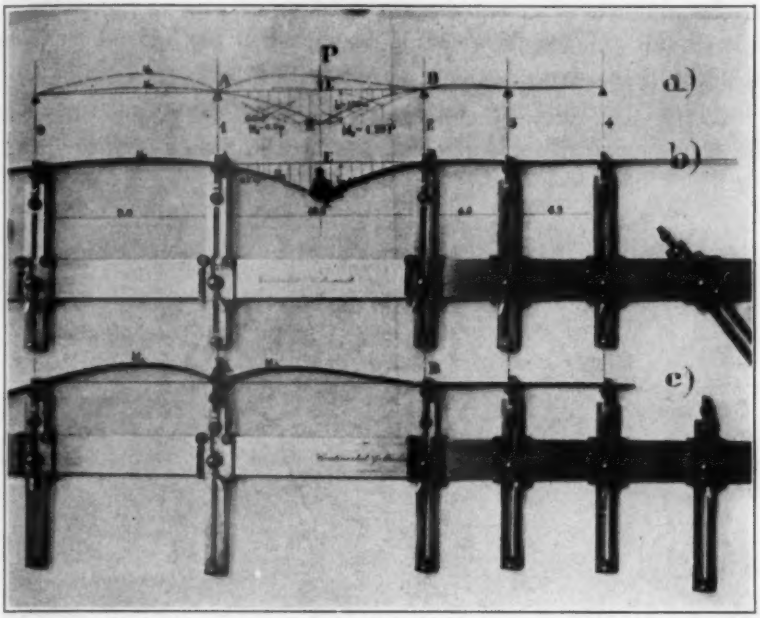
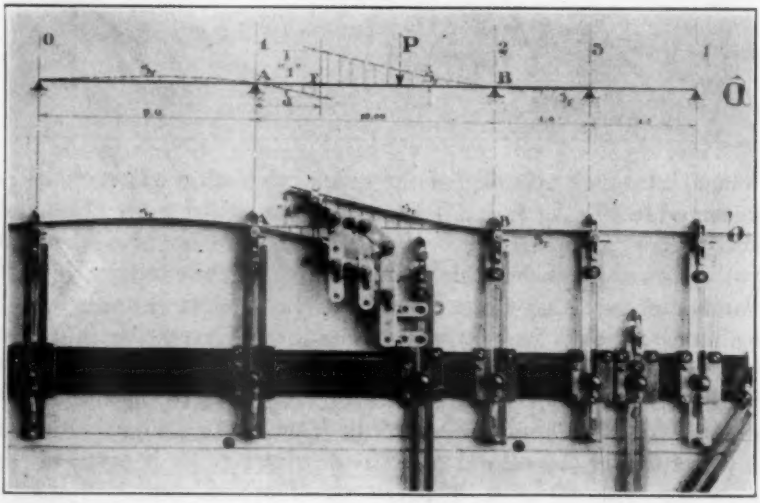


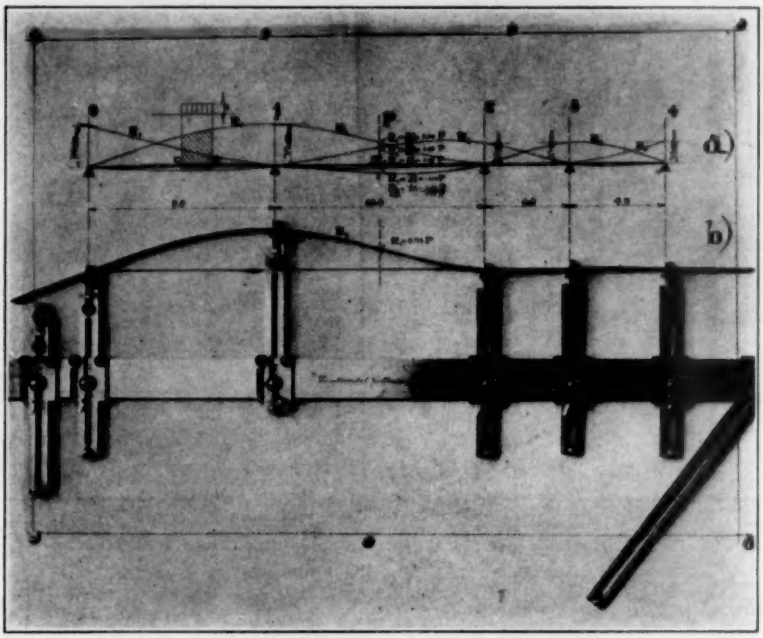
FIG. 11.



(Fig. 12 *b*) through 4 cm., the elastic tape which passes through all the supports describes a curve whose ordinate at the point E is 2.16 cm. Hence the reaction produced in the second support by the load P which acts at E is $R = \frac{2.16}{4.00} P = 0.54 P$.

In the same way we can trace instantly the influence lines of the reactions at all the supports as they are marked on Fig. 12 *a*.

FIG. 12.



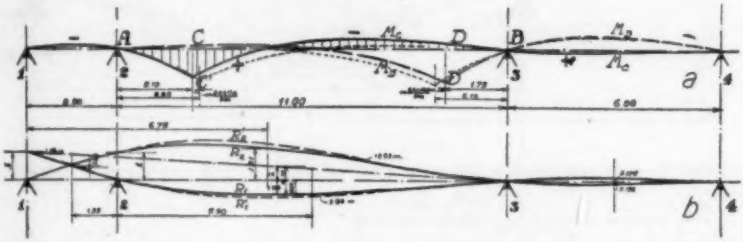
(3) Another example of the quick calculation of reactions is presented in Fig. 13 *b*, in a beam of three spans of 2.50, 11.00 and 6.00 metres, respectively. We displace on the plan through (1) = 1.5 cm., first the scale corresponding to the exterior support 1 and afterward that corresponding to the support 2, and read off ordinates at loads or mark on the plan the respective influence lines; we obtain thus the influence lines R_1, and R_2, drawn in full lines in Fig. 13 *b*. The ordinate of the curve R_1 in the centre of the first span divided by 1.5 cm. results ($\frac{1}{2} - 0.04$) and that in the centre of the second span divided by 1.5 cm. is 0.52; in the same way the curve R_2 between the supports 1 and 3, whose

distance between each other is 2.50 + 11.00 = 13.50 m., has at the centre, that is, at 6.75 m. from the support 1, the ordinate divided by 1.5 cm. = 1.21. Then, the reactions R_1 and R_2, produced by the concentrated load P, are equal to the product of such load by the ordinate of the curves at the point where it acts. Supposing, on the other hand, a uniform load $P.t/m$ between the supports L and 3, the result is,

$$R_1 = (\tfrac{1}{2} \times 2.50 \times 1.0 - \tfrac{2}{3} \times 2.50 \times 0.04 - \tfrac{2}{3} \times 11.00 \times 0.52)P$$
$$= -\tfrac{2}{3} \times 1.033 \times 13.50 + \tfrac{1}{2} \times 1.0 \times 13.50$$
$$= -2.66 \text{ m. p. kg./m.} = -2.66 \text{ p. kg.}$$
$$R_2 = \tfrac{2}{3}\ (2.50 + 11.00)\ 1.21 \text{ p.} = 10.93 \text{ p. kg.}$$

When we increase the moment of inertia at the support 2 to double that at the middle parts of the span, the reaction 1 dimin-

FIG. 13.



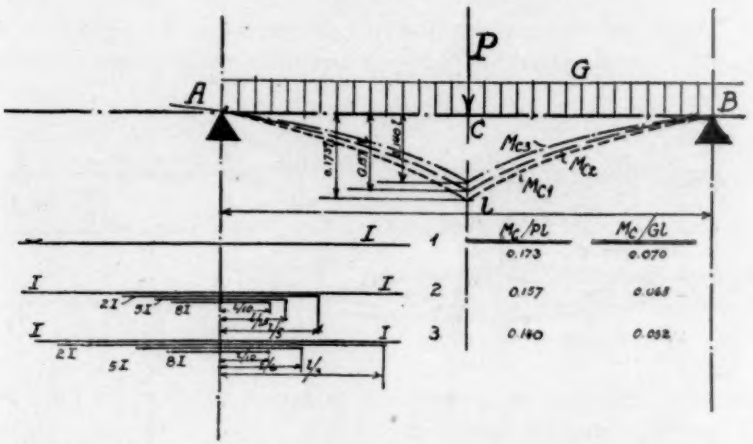
ishes and the reaction 2 increases, as can be noted in the cut lines R_1 and R_2 from the same Fig. 13 *b*.

(4) To be able to judge, in the continuous beam of reinforced concrete of spans 2.50, 11.00 and 6.00 m., represented in Fig. 13 *a*, up to what section of the span *AB* top reinforcement should be placed, we determine instantly with the "Continostat" the points *C* and *D* at 2.10 and 1.75, respectively, from the supports 2 and 3 whose influence area for M_C and M_D equals zero, the positive and negative parts compensating. This can be determined easily at sight, slipping the broken steel ribbon, because moving the clamp No. 2 which forms the break, a little more inside, the positive surfaces increase so much that even with live load very great in comparison to the dead load, no negative moment need be expected. As a simple rule we can suppose that there will be no negative moments interior to the sections *C* and *B* more than 1/2000 part of the product of the two spans adjacent to the respective support.

(5) In the interior span AB of a continuous beam, the bending moments at the centre C, according to the influence line M_C, are shown in Fig. 14. It is required to reduce these moments at the centre, reinforcing the beam at the supports. We place short pieces of splines which suit best the supposed reinforcing, by which action the curve of the influence line is automatically raised as per Fig. 14.

Placing ribbons of 0.5 mm. thickness with others of 0.72 mm. of the same material, 0.72^3 being approximately equal to 3×0.5^3,

FIG. 14.



we can obtain the combinations 1, 2, and 3, indicated in Fig. 14. The reductions of the bending in the centre which are thus obtained for a concentrated load P are 9½ per cent. and 19 per cent., respectively; for a uniform load G, on the other hand, the reductions are respectively 10½ and 26½.

In order that the reinforcement at the supports should properly relieve the centre, it is important that it approach as much as possible the centre of the spans.

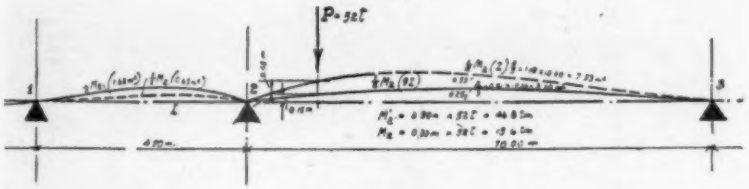
(6) The lack of time many times prevents the taking into account the variations of the moments of inertia in the separate spans of continuous beams and generally professional men do not realize the magnitude of errors which are thus made.

In Fig. 15 the interior spans of a continuous beam are 4.50 and 10.00 metres, respectively. The last span is loaded at a

distance of 1.50 metres from support 2 by a concentrated load $P = 52\ t$. Required, the bending moment at support 2.

Supposing a constant moment of inertia, the influence line marked M'_2, as per Fig. 15, results, which at 1.50 metres from support 2 determines an ordinate of $2 \times 0.45 = 0.90$ metre, hence $M'_2 = 0.90 \times 52.0 = 46.8\ t/m$. Adding now in the span 2 to 3 a spline of double thickness, that is, of eight times the moment of inertia, the ordinate at the load $= 2 \times 0.15 = 0.30$ m.; hence $M_2 = 0.30 \times 52 = 15.6\ t/m$ or only one-third of the assumed bending moment M_2. This means that according to the accustomed method an error of 200 per cent. is made. If the two spans in question were loaded with a uniform load g in t/m the

FIG. 15.



bending moment, with the influence areas indicated in Fig. 15, would be $M'_2 = (7.35 + 0.63)\ g = 7.96\ g$ instead of $M_2 = (3.40 + 1.62)\ g = 5.02\ g/tm$, hence there is an error of not less than 59 per cent.

5. PORTALS.

In Figs. 1 to 5 the application of the mechanical methods to non-rectilinear systems has been clearly demonstrated. Then a portal of one opening with brackets was treated.

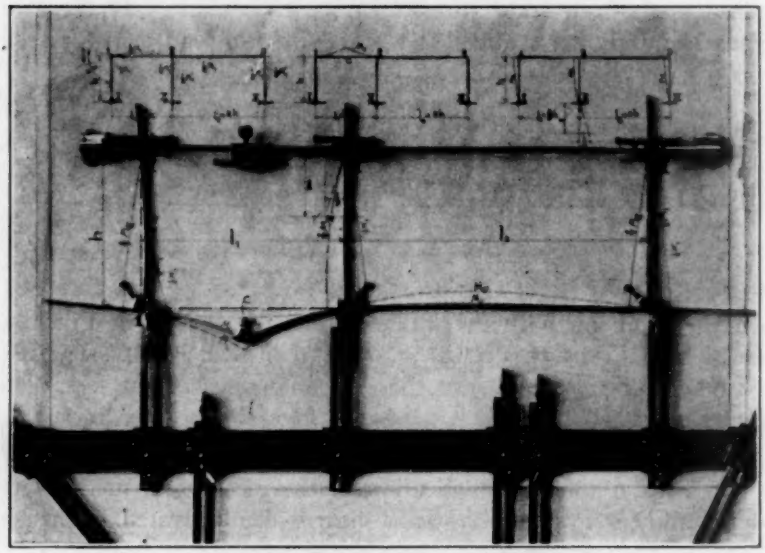
The process indicated is not changed in any way with a greater number of openings and when the columns are fixed at the bases. Figs. 16, 17 and 18 reproduce the automatic calculations of a portal of two separate spans l_1 and l_2 and height h, whose central column is fixed at the base.

With this object we build up upside down the system rapidly, using spliced clamp called No. 1, and place it over the plan drawn on cross-section paper, holding it firmly at the points of junction at distances l_1 and l_2 with the counter-scale which runs without friction on rollers at its two ends, and over which holders slip.

To calculate the bending moment at the centre C of the first span, we join (as per Fig. 16) two pieces of ribbon at C with the

clamp No. 2, taking good care that the bases of the columns keep exactly their distance by means of the holders on the counter-scale, and that the spline of the second column be perpendicular at its base, and we slip the whole "Continostat" with the elastic model until the supports of the columns return to their original position. We mark the curves described by the model which altogether form the influence line of the bending moment M_C. To find the moment M_C which a load P acting at any point produces

FIG. 16.



in C, we multiply P by the ordinates which the curve determines with respect to the original system, which in Fig. 16 is shown by the dotted line. The dotted line which in Fig. 13 passes through the points 1, 2 and 3 is the influence line of M_C for the continuous beam of spans l_1 and l_2, which would result if we do not take into consideration its fixing to the columns, resulting with ordinates and hence with moments M_C much larger. To find the horizontal displacement H_{II} we displace on the counter-scale the holder at support II (Fig. 17) one unit, 3 cm. for example. The support II being fixed, we take good care that the position of the ribbon at II be vertical by means of the set screws of the holder clamp; then we let the "Continostat" slide again on the large

FIG. 17.

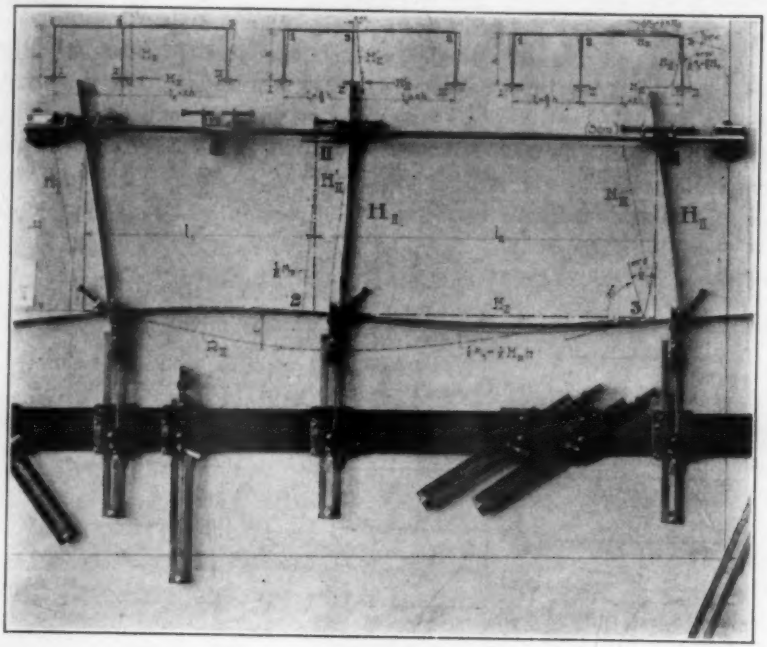
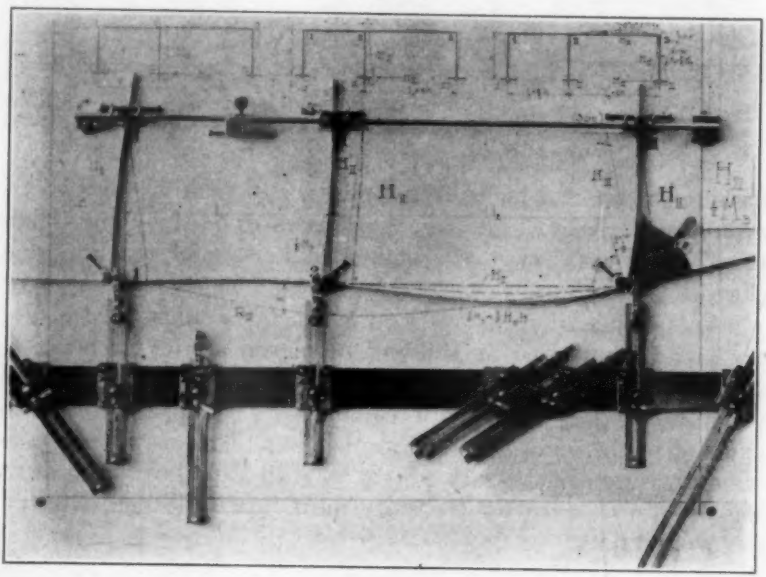


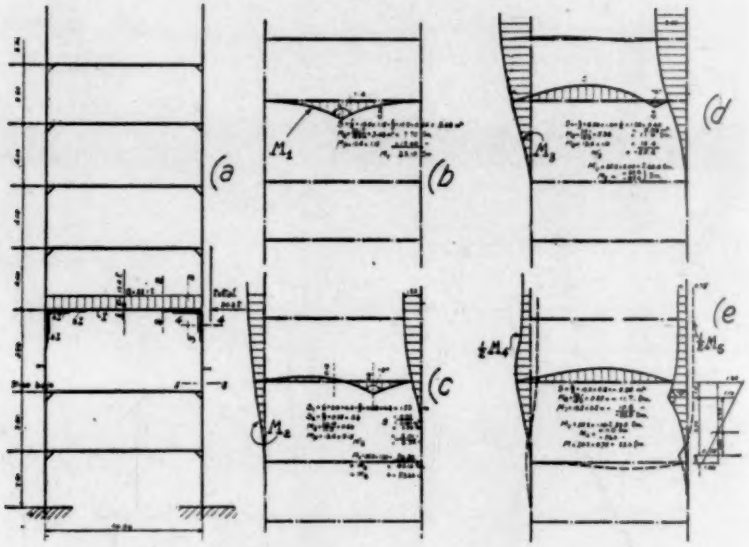
FIG. 18.



tacks which guide below the principal rod in a horizontal direction and we have the influence line for H_{II}.

Further, we automatically obtain the line of the bending moment M_3 (Fig. 18), at the corner 3, rotating through a unit, the column III_3 and the beam 1–2–3, one with respect to the other, and slipping the apparatus with the drawing until the bases of the columns return to their original place on the plan. To avoid disproportionate deformations, a rotation (Fig. 18) of only ½

FIG. 19.



has been made and hence it is necessary to multiply by two the ordinates obtained. The same ordinates divided by the height h of the portal serve to obtain the horizontal reaction H_{III} since $M_3 = h \times H_{III}$.

An example of the application in practice is illustrated in Fig. 19. The framing of a building of eleven stories in height is treated, including the two basements and only 10 metres wide, centre to centre, of exterior columns. The upper stories are exposed to the wind and the framing has therefore to resist the wind pressure over a width of 9.25 m with a total of 30.2 t at the highest story, hence for the story most heavily loaded, which is the ground floor.

It be required to determine the bending moments in the sections 1–1 to 5–5 produced by the vertical loads and by the horizontal pressure of the wind indicated.

We compose rapidly the example by means of splines and clamps No. 1, taking into account the increase in the moment of inertia by additional splines as indicated in Fig. 19 *a*.

In the centre of upper beam of the first floor we use the clamp No. 2 as indicated in Fig. 19 *b*, and it is interesting to note the influence of the reinforcement at the ends of the beam, inasmuch as a uniform load of 22.1 *t* over the span of 10 metres gives a moment of only 7.70 *t/m* or $\frac{P \times l}{28.7}$, or less than in a beam completely fixed and of uniform section.

In the other sections which are near the corners, we use the clamp No. 3, whose angle corresponds to the half rotation at fixed supports. All the moments are noted in Fig. 19 *a*, *b*, *c*, and *d*. The line of influence in regards to the horizontal displacement, which corresponds to the influence of the horizontal wind pressure, is very interesting. It is noted that at a few metres above the deformed floor this line runs completely vertical, that is, the height where the wind acts does not matter, as far as bending moments in the beams are concerned.

The horizontal displacement of the deformed system, that is, the bending moment produced by the wind, is nil in the centre of the horizontal beams (as per Fig. 19 *b*) and in a certain section of the columns (as per Fig. 19 *c*).

6. TRUSSES WITHOUT DIAGONALS.

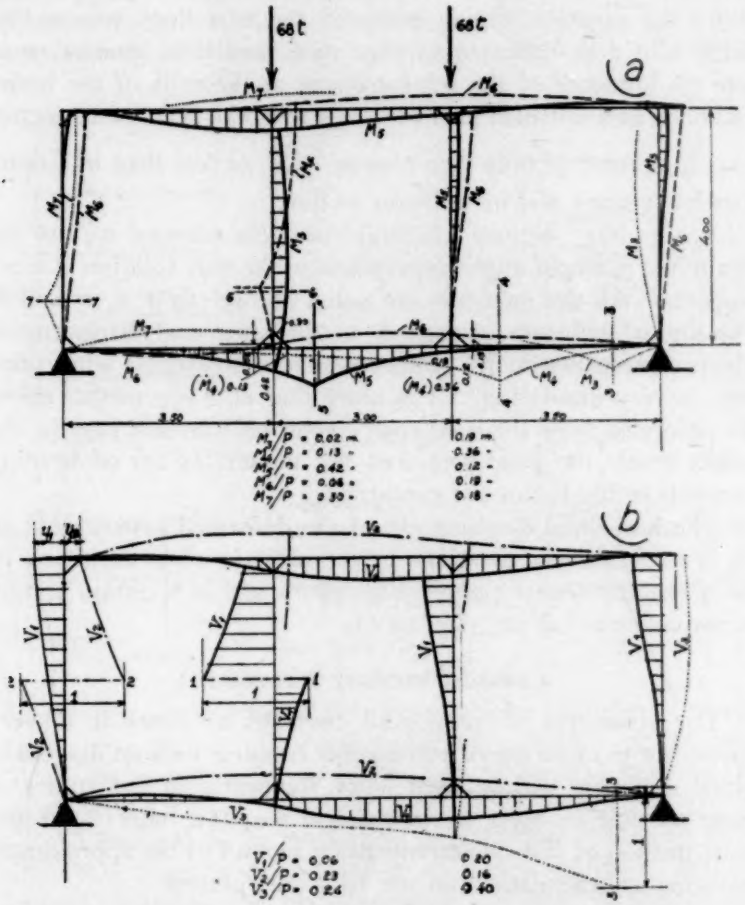
For structures of reinforced concrete, at times it is very convenient to make use of rectangular framing without diagonals, which doubtless will be used more frequently in the future, it being possible to apply by mechanical means a more rapid and exact method of statical determination instead of the approximate mathematical calculations in use up to the present.

A typical problem is solved in Fig. 20. The façade of the same building, whose interior structure was calculated as per Fig. 19, has two lines of interior columns throughout its height, except in the ground floor.

The most convenient design was a rigid frame, using the

front beams of the first and second stories and the four vertical columns. Placing the clamp (o) at the point (5–5) of the lower chord, the influence line of the bending moments at 5–5 results as per Fig. 20 *a*. (Remember that when using the clamp No. 3 it is

FIG. 20.

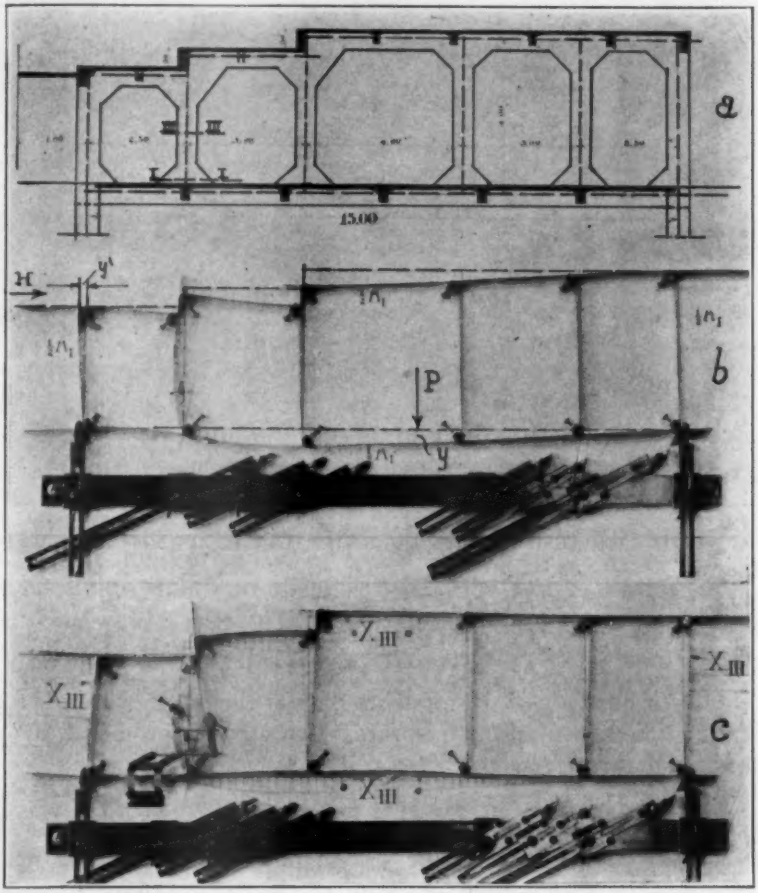


necessary to multiply the ordinates of influence line obtained by 2.) In the same manner the bending moments of sections 3–3, 4–4, 6–6, and 7–7, whose influence lines are shown in Fig. 20 by the dotted lines, are obtained.

With the ordinates and the loads shown on the same Fig. 20, we have then the following bending moments:

$M_3 = 68.0\,t\,(0.02 + 0.19),\ m = 14.28\ tm$ $\quad M_5 = 68.0\,t\,(0.42 + 0.12),\ m = 36.72\ tm$
$M_4 = 68.0\,t\,(0.13 + 0.36),\ m = 32.32\ tm$ $\quad M_6 = 68.0\,t\,(0.06 + 0.19),\ m = 17.00\ tm$
$M_7 = 68.0\,t\,(0.30 + 0.18),\ m = 32.64\ tm$

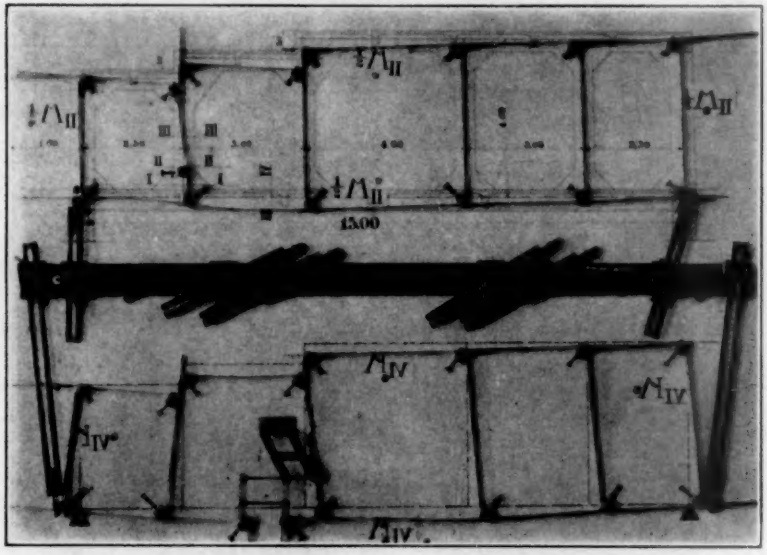
FIG. 21.



In Fig. 20 *b*, on the other hand, are shown the influence lines of the shears in sections 1–1, 2–2 and 3–3, obtained by separating through a unit length in a transverse direction two adjacent sections, holding the end of the ribbon thus out parallel between them.

The areas of influence shaded, correspond to the shear V_1 in section 1–1. So the unit dimension at section 1–1, as well as ordinates, have been exaggerated with respect to the dimensions of the frame for clearness. With the ordinates divided by unity,

FIG. 22.



shown in each case in Fig. 20 *b*, the calculation of the shears results as follows:

$$V_1 = 68.0\,t\,(0.06 + 0.20) = 17.68\,t$$
$$V_2 = 68.0\,t\,(0.23 + 0.16) = 26.52\,t$$
$$V_3 = 68.0\,t\,(0.24 + 0.40) = 43.52\,t$$

The ordinates y of the influence lines at the top chord show the bending moments and the shears, respectively, produced by a horizontal force H which acts on it.

In Fig. 21 *a* is represented an irregular beam (Vierendeel) of 15 metres span and 4 metres high, whose top chord is stepped. Producing at the base of the second post the rotation ½ with respect to the lower chord by means of clamp No. 4, according to Fig. 21 *b*, the drawing of the beam takes automatically the form of the influence line of the bending moments at the section 1–1. A vertical load P produces at 1–1 a bending moment Py, the horizontal load H which acts on the top chord, a moment Hy'.

Separating the ribbon at III–III, as per Fig. 21 *c*, with neither axial displacement nor rotation at the ends of the separation, we obtain the influence line of the shear X_{III}.

In the same manner we obtain, as per Fig. 22 *a*, the influence line of the bending moments M_{II} which act on section II–II. Using the clamp No. 3 (see previous note) and according to Fig. 22 *b*, the influence line of the normal forces N_{IV}, which causes compression or tension at section IV. In the same manner the influence line of the shear further up is obtained. For a load P, as indicated in Fig. 22, results then, the bending moment

$$M_{II} = 2yP, \text{ and the normal force } N_{IV} = \frac{y'}{s} P.$$

7. PRECISION OF RESULTS.

The basis on which the mechanical methods explained in this article are founded being unquestionably correct, the results also will always be correct if, during the operations, we avoid the exceeding of the limit of the elasticity of the material of the elastic ribbons, and always maintain relatively small the interior works of deformation, and the lengths of the various members of the drawing of the structure.

Comparison with results obtained by mathematical methods usually permits the announcement of the following general observations.

(1) Bending moments, obtained by means of the clamp No. 2 in the 3/5 interior portion of beams and columns, give surprising agreement with results obtained mathematically. Even without great precaution the results in continuous beams do not differ more than 2 per cent. for readings in the span to be calculated. Therefore, we can generally calculate easily the whole beam knowing the bending moment at the centre, and the latter is recommended in preference for the determination.

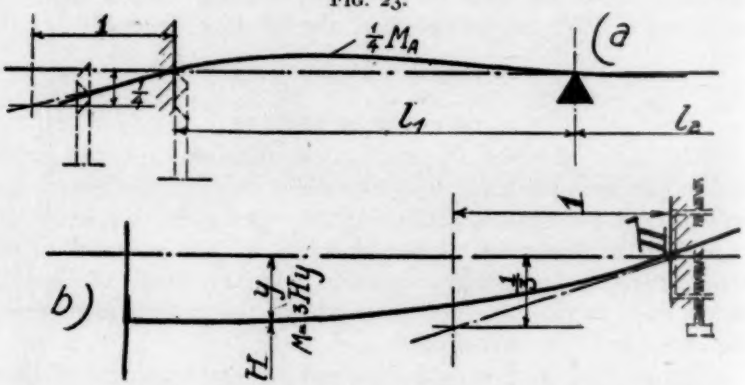
(2) For reasons explained at the beginning of this article we use, near the supports of beams and tops of columns, the clamps No. 3 or 4, which determine the influence line of the bending moments, multiplying the ordinates obtained by 2. In cases of completely fixed beams the use of clamps is unnecessary, turning the ribbon at the point of support 1/4 or maximum 1/3, as suggested in Fig. 23. It is easy to maintain the difference within 6 per cent., comparing with mathematical calculations.

(3) The linear displacements which we use, for example, for

determining reactions, shears, and normal forces, ought not as far as possible to exceed 1/5 part of the distance from the section displaced to the nearest point of support of the same member of the structure. With this precaution the ordinates result exact; errors in reading might amount to 4 per cent.

(4) In structures which are not rectilinear, it is convenient to produce the displacements desired, first in one direction and afterwards in the opposite direction, thus we neutralize somewhat

FIG. 23.



the errors in the one or the other position. At the same time in this way ordinates greater and easier to read correctly result.

If we take into account that the values of the dead loads and live loads for different structures at times differ up to 30 per cent. one from the other, and considering the enormous errors to which the usual suppositions, necessary for mathematical calculations, can lead, the possible errors indicated in this article are insignificant. Moreover, it is necessary to note that, especially in portals, the results obtained automatically correspond better to the actual conditions of the work than the suppositions that it is necessary to assume in order to make possible mathematical calculations.

8. CHECKING RESULTS THROUGH ACTUAL DEFORMATIONS.

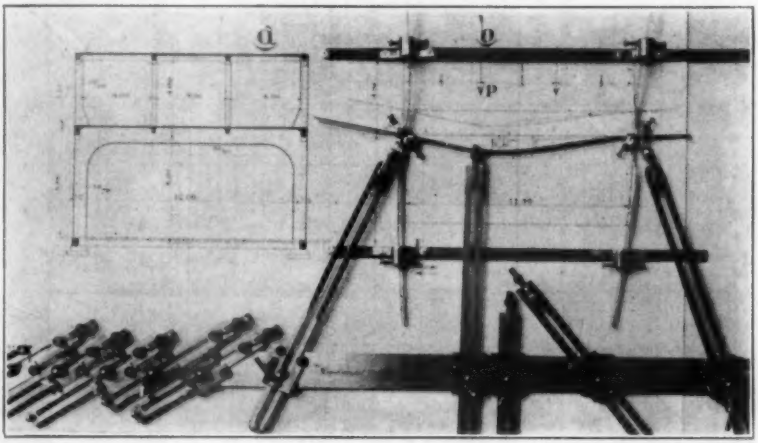
Let AB be a beam, originally straight, which forms part of any elastic structure and whose section is constant throughout its length. Acting on this beam is any load P; there results an elastic line as per figure on the table shown below, whose deflection at the centre of AB is h, and whose tangents at the supports determine on the vertical at the centre, the segments f_A and f_B, respec-

tively. The relation between f_A, f_B and h depends only on the kind of load whatever be its intensity.

The author has been able to discover exact expressions to determine the moments with AB partially fixed, when knowing the length of f_A and f_B and the kind of load.[3] In the adjoining table the coefficients obtained have been compiled.

As an example is shown in Fig. 24 *a*, the drawing of the framework of a large hotel, constructed recently in territory subject to seismic disturbances. To compute the bending moment in

FIG. 24.



the beam of 12 metres long we hold the corresponding spline at the ends as per Fig. 24 *b*, and load the same with a movable scale at the centre of one of the interior columns, that is, at the third point, until the deflection at the centre reached a convenient round value, for instance, 3 cm. Then we trace the tangents at the supports and we measure f_A and f_B. Then the results are:

$$M_A = m_A \times Pl \text{ and } M_B = m_B \times Pl,$$

where according to the table below—

$$m_A = (48h - 22f_A - 7f_B) / 81 (4h - f_A - f_B)$$

and

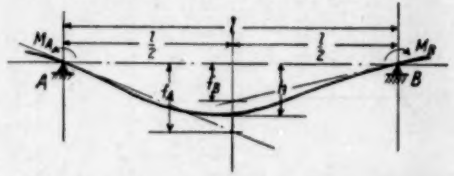
$$m_B = (24h - 16f_B - f_A) / 81 (4h - f_A - f_B)$$

P = the column load and l = length of the beam.

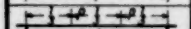
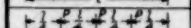
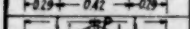
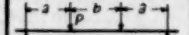
This method can give good results for the computation of any

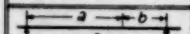
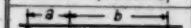
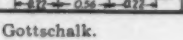
[3] *Anales de la Sociedad Cientifica Argentine*, t. XCVI, p. 177, 1923, and *Der Bau-Ingenieur*, Berlin, May 15, 1924.

Moments Of Constraint



$D = 4h - f_A - f_B$ $\quad M_A = m_A Pl$ $\quad M_B = m_B Pl$

LOAD	$m_A D$	$m_B D$
	$\frac{1}{24}(12h - 7f_A - f_B)$	$\frac{1}{24}(12h - 7f_B - f_A)$
	$\frac{2}{81}(36h - 19f_A - 4f_B)$	$\frac{2}{81}(36h - 19f_B - 4f_A)$
	$\frac{1}{48}(60h - 31f_A - 7f_B)$	$\frac{1}{48}(60h - 31f_B - 7f_A)$
	$\frac{1}{24}(8h - 4f_A - f_B)$	$\frac{1}{24}(8h - 4f_B - f_A)$
	$\frac{1}{240}(100h - 53f_A - 11f_B)$	$\frac{1}{240}(100h - 53f_B - 11f_A)$
	$\frac{2}{31}\left[12\left(1-\frac{a}{l}\right)h - \left(3+9\frac{a}{l}-15\frac{a^2}{l^2}\right)f_A - \left(3-9\frac{a}{l}+8\frac{a^2}{l^2}\right)f_B\right]$	$\frac{2}{31}\left[12\left(1+\frac{a}{l}\right)h - \left(3+9\frac{a}{l}-16\frac{a^2}{l^2}\right)f_B - \left(3-9\frac{a}{l}+8\frac{a^2}{l^2}\right)f_A\right]$
	$\frac{1}{24}\left[\left(12-4\frac{a^2}{l^2}\right)h - \left(1-21\frac{a^2}{l^2}+18\frac{a^3}{l^3}\right)f_A - \left(1+9\frac{a^2}{l^2}-9\frac{a^3}{l^3}\right)f_B\right]$	$\frac{1}{24}\left[\left(12-4\frac{a^2}{l^2}\right)h - \left(1-21\frac{a^2}{l^2}+18\frac{a^3}{l^3}\right)f_B - \left(1+9\frac{a^2}{l^2}-9\frac{a^3}{l^3}\right)f_A\right]$

LOAD			$m_A D$	$m_B D$
			$\frac{b^2}{3l^3}(12\frac{a}{b}h - (9\frac{l}{b}-11)f_A - f_B$	$\frac{a^2}{3l^3}(12\frac{b^2}{a^2}h - (3\frac{b^3}{a^3}-5)f_B - (3\frac{b^3}{a^3}-9\frac{b}{a}+7)f_A$
			$\frac{a^2}{3l^3}(12\frac{b^2}{a^2}h - (3\frac{b^3}{a^3}-5)f_A - 3\frac{b^3}{a^3}+9\frac{b}{a}+7)f_B$	$\frac{a^2}{3l^3}(12\frac{b}{a}h - 19\frac{b}{a}-11)f_B - f_A)$
$\frac{a}{l}$	$\frac{b}{l}$	$\frac{a}{b}$		
$\frac{1}{10}$	$\frac{9}{10}$	$\frac{1}{9}$	$\frac{1}{5000}(972h - 295f_A - 217f_B)$	$\frac{1}{5000}(108h - 79f_B - f_A)$
$\frac{1}{5}$	$\frac{4}{5}$	$\frac{1}{4}$	$\frac{1}{375}(192h - 70f_A - 37f_B)$	$\frac{1}{375}(48h - 34f_B - f_A)$
$\frac{1}{4}$	$\frac{3}{4}$	$\frac{1}{3}$	$\frac{1}{192}(108h - 43f_A - 19f_B)$	$\frac{1}{192}(36h - 25f_B - f_A)$
$\frac{1}{3}$	$\frac{2}{3}$	$\frac{1}{2}$	$\frac{1}{81}(48h - 22f_A - 7f_B)$	$\frac{1}{81}(24h - 16f_B - f_A)$
$\frac{2}{5}$	$\frac{3}{5}$	$\frac{3}{2}$	$\frac{2}{375}(27h - \frac{55}{4}f_A - \frac{13}{4}f_B)$	$\frac{2}{375}(18h - \frac{23}{2}f_B - f_A)$
$\frac{1}{2}$	$\frac{1}{2}$	1	$\frac{1}{24}(12h - 7f_A - f_B)$	$\frac{1}{24}(12h - 7f_B - f_A)$
$\frac{3}{5}$	$\frac{2}{5}$	$\frac{3}{2}$	$\frac{2}{375}(18h - \frac{23}{2}f_A - f_B)$	$\frac{2}{375}(27h - \frac{55}{4}f_B - \frac{13}{4}f_A)$
$\frac{2}{3}$	$\frac{1}{3}$	2	$\frac{1}{81}(24h - 16f_A - f_B)$	$\frac{1}{81}(48h - 22f_B - 7f_B)$
$\frac{3}{4}$	$\frac{1}{4}$	3	$\frac{1}{192}(36h - 25f_A - f_B)$	$\frac{1}{192}(108h - 43f_B - 19f_A)$
$\frac{4}{5}$	$\frac{1}{5}$	4	$\frac{1}{375}(45h - 34f_A - f_B)$	$\frac{1}{375}(192h - 70f_B - 37f_A)$
$\frac{9}{10}$	$\frac{1}{10}$	9	$\frac{1}{5000}(108h - 79f_A - f_B)$	$\frac{1}{5000}(972 - 295f_B - 217f_A)$
			$\frac{1}{120}(32h - 18f_A - 3f_B)$	$\frac{1}{120}(48h - 22f_B - 7f_A)$
			$\frac{1}{80}(20h - 9f_A - 3f_B)$	$\frac{1}{80}(20h - 9f_B - 3f_A)$

Continostat Gottschalk.

beam which forms part of a complicated structure. It permits us to disregard completely the other members of the structure, whose relative rigidity is expressed automatically in the inclination of the tangents at supports. Uniform loads are substituted by two equal concentrated loads which two movable scales of equal force produce, pulled by two rollers provided for this purpose with a silk thread. For uniformly distributed loads the two forces ought to act as $0.29\,l$ from the two supports as indicated in the drawings in the table.

Errors admissible in this process reach 10 per cent. Reinforcements at the supports do not appreciably affect the exactness of the results. Although the coefficients indicated have been calculated, assuming a constant section throughout the span of the beam, they are correct with a sufficient exactness when the latter has reinforcements at the supports.

9. FINAL CONSIDERATIONS.

The examples above detailed indicate the result obtained through mechanical methods of statical calculations by the Continostat Gottschalk. Students can appreciate the fundamental progress that the substitution for abstract and dead formulæ with intuition means as much for the mentality and the development of the artistic mind of the student as well as for the professional, whose many tasks do not permit him to enter each time on new secrets of formulæ and tables. We are able to affirm that with more intuition and fewer formulæ we can make more competent engineers and better structures. Whilst up to now the development to which I allude has been only in charge of the author, in a short time after the publication of the first articles on this matter, the instrument and the methods have been adopted by the Universities of Buenos Aires, of La Plata, of Rosario de Santa Fe, and also by military schools, and by public and private technical offices, all of which in the future, causes the hope for important discoveries in the methods explained in this treatise, contributing valuable ideas to the profession and science.

I wish to make grateful expression of my appreciation for the helpful labors of my friend, Mr. B. R. Hayward, of the Department of Bridge Design of the City of Chicago, who with marked kindness translated this article from the original Spanish into English.

The Increase of the Conductivity of Solid Dielectrics Due to Illumination by X-rays. C. Roos. (*Zeit. f. Physik.*, 36, No. 1.)—Soon after the discovery of X-rays J. J. Thomson and McClelland published results showing that paraffin and sulphur become conductors under the influence of the new radiation and that the gain in conductivity is roughly proportional to the intensity of the incident radiation. Others have confirmed and extended the early results.

In this series of investigations sulphur, paraffin, hard rubber and amber were used. In none of them was any conductivity of measurable quantity found so long as the substances were in the dark. In sulphur under X-ray illumination a strict proportionality was shown to exist between the current passing through the substance and the applied voltage, that is, Ohm's law was followed. In the case of the other three, however, the employment of about 100 volts produced a current that was scarcely increased by a further increase of voltage. The curve connecting current and voltage is a typical saturation curve. For sulphur the current transmitted grows less as the wave-length of the acting X-rays increases. For example, the current, when sulphur is under the influence of radiation of wave-length .21 A.U., is more than twice as great as when radiation of length .40 A.U. is incident. G. F. S.

Restoring the Man-of-War, "Constitution." (U. S. Department of Agriculture, Clip Sheet No. 414, June 7, 1926.)—In restoring America's famous old man-of-war, the *Constitution*, the Forest Service has been called upon to help in the search for suitable timbers.

Built in the days when this country had an abundance of excellent oak timbers for shipbuilding purposes, the old 44-gun frigate originally contained timbers, principally of oak, which those in charge of its restoration are eager to duplicate. It was hoped to find some of the needed material on three islands off the coast of Georgia which had been set aside in the days of wooden vessels as timber reserves for the United States Navy. Accordingly, Government forestry and logging experts have just completed a survey of these islands and report that oak timbers of the kind required are not available in sufficient quantity. However, they have found pine timber suitable for deck beams, planking, and ceiling on Grover Island.

Extension of the X-ray Spectrum toward the Ultra-violet. A. DAUVILLIER. (*Comptes Rendus*, May 3, 1926.)—In 1924 Thoraeus and Siegbahn succeeded in extending the spectrum of X-rays to a length as great as 21.7 A.U. For this they employed a grating of palmitic acid. In the present investigation a cathode of graphite was used. The X-rays from it were incident upon a grating of melissic acid deposited on lead. From this was isolated an intense ray of wave-length 45.3 A.U., the only radiation in the K spectrum of carbon. Thus an advance is made into a new region of the spectrum. G. F. S.

THE TESTING OF PAINT PIGMENTS FOR TRANSPARENCY TO ULTRA-VIOLET RADIATION.*

BY

GEORGE F. A. STUTZ, A.M.

Physicist, Research Division, The New Jersey Zinc Company.

AN important property of paint pigments is the absorption and transmission of light. The transmission of ultra-violet light by paint pigments is of particular interest because of the effect of such radiations on paint films.[1]

A. H. Pfund [2] measured the relative transmission of the several white pigments by determining the coefficient of diffuse reflection in the ultra-violet. The writer has made the same determination for a number of other pigments.[3] Light, falling upon a thick layer of pigment particles, penetrates a large number of particles before being finally returned. Hence the absorption shown in reflected light is similar to that shown in transmitted light, and a determination of the coefficient of diffuse reflection from a dry pigment surface gives a relative measure of the transparency of the material in question. Such a determination, however, is only relative, and does not indicate to what depth the light penetrates before being reflected or absorbed.

Pfund [2] also measured the transparency to ultra-violet light, of films of wet linseed oil containing white pigments and inerts. The absorption of light by the oil and the diffusing effect of the pigment combined to render these results somewhat inaccurate.

Hallett [4] made a somewhat similar determination of the ultra-violet light reflected and transmitted by a dry paint film, but the high absorption of dry linseed oil in this region makes it impossible to draw from his work any accurate conclusion as to the transparency of the pigment alone.

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* A contribution from the Research Laboratory of the New Jersey Zinc Company. Communicated by the Chief of the Research Division.

[1] H. A. NELSON, *Proc. Am. Soc. Test. Mat.*, **22**, Part II, p. 485 (1922).

[2] A. H. PFUND, *Proc. Am. Soc. Test. Mat.*, **23**, Part II, p. 369 (1923).

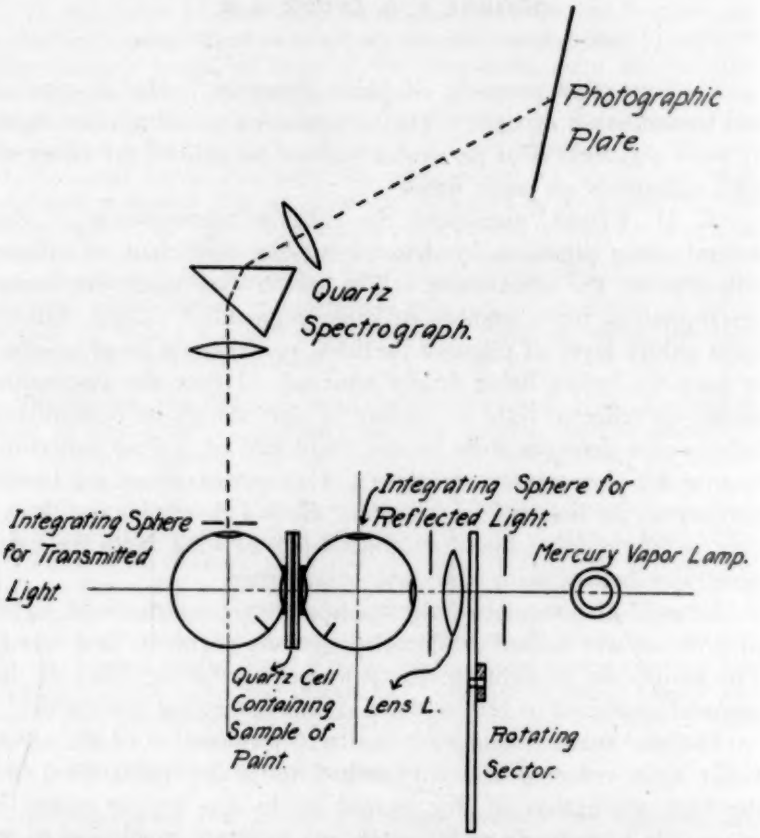
[3] G. F. A. STUTZ, JOUR. FRANK. INST., July, 1925, p. 87.

[4] R. L. HALLETT, *Proc. Am. Soc. Test. Mat.*, **23**, Part II, p. 379 (1923).

APPARATUS AND METHOD.

In this work, the apparatus has been modified as suggested by Doctor Pfund, so that both the reflected and the transmitted light are caught in diffusely reflecting spheres. The arrangement is shown in Fig. 1. Light from the quartz-mercury lamp is ren-

FIG. 1.

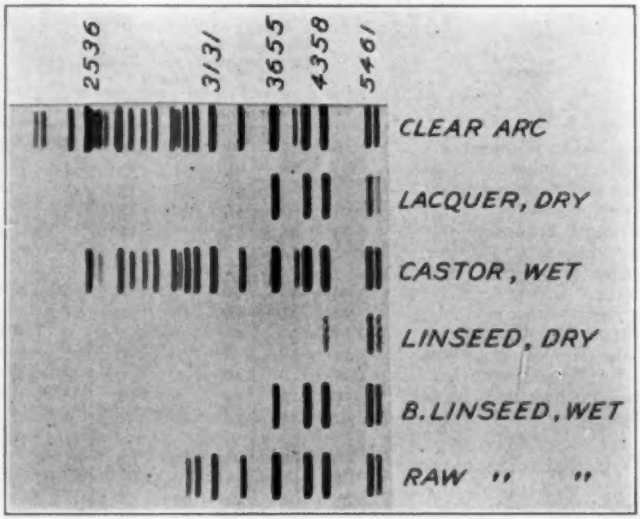


dered parallel by the quartz lens L, and impinges on the paint film contained in the quartz cell. The total transmitted light is caught by the magnesium-oxide-coated sphere and enters the quartz spectrograph as shown. The light reflected by the film is collected in a similar sphere. The whole apparatus is mounted on a slide, so that it can be moved to the left until the light from the second sphere enters the spectrograph.

The amount of light reflected and transmitted in each case was measured by the darkening produced on the photographic plate. The rotating sector was used to give a series of comparison spectra of known amount, transmission being made through a cell containing the clear vehicle, and reflection being made from a surface of magnesium carbonate.

The cell used consisted of two quartz plates with a bronze separator, .09 mm. thick. The pigments were incorporated in

FIG. 2.



Spectrograms of the light from the quartz-mercury arc after passing through a film of clear vehicle .09 mm. thick.

castor oil, since this has practically no absorption in the wave-length interval from 4400 to 2900 Å.U. The absorption effected by linseed oil and lacquer is shown in Fig. 2. The spectrum in each case is that of the light of the quartz-mercury arc after passing through a vehicle film .09 mm. thick. For more complete data on the absorption of ultra-violet light by vehicles the reader is referred to a previous paper.[3]

A weight of pigment equal to .053 c.c. (calculated from the density) was incorporated in 5 c.c. of castor oil. This is an approximate volume ratio of 1 per cent. pigment, 99 per cent. vehicle. When this mixture was placed in a cell .09 mm. thick,

the amount of pigment in the cell was sufficient to form a layer .00092 mm. thick. The thickness of the pigment layer was varied in some cases by the addition of a greater or less volume of pigment.

RESULTS.

Since the reflection factors parallel those of Pfund and the writer, the transmission measurements only will be presented.

TABLE I.

White Pigment—Inerts—Blacks.

Pigment.	Per cent. Transmission of Pigment .00092 mm. Thick at Wave-length						Thickness at Which Pigment Is Opaque to 3655 in mm.
	4358	4047	3655	3342	3131	3023	
Antimony oxide pigment	48	47	39	24	10	0	.0065
Basic lead carbonate	69	66	61	57.5	55	54	.0270
Basic lead sulphate	71	63	40	35	35	35	.0052
Lithopone	56	52	43	32	15	5	.0100
Extra-strength lithopone	50	43.5	31	20	12	8	.0085
Pigment composite (40 per cent. lithopone, 40 per cent. zinc oxide, 20 per cent. inert)	50	43	12	7	6	6	.0020
Titanium pigment	39	39	18	13	12	11.5	.0046
100 per cent. titanium dioxide	35	32	18	6	.5	0	.0031
Zinc oxide (American process)	44	38	0	0	0	0	.0009
Zinc oxide (French process)	46	40	0	0	0	0	.0009
Zinc oxide (35 per cent. leaded)	50	45	9	8.5	8	8	.0015
Zinc sulphide	30	28	22	10.5	0	0	.0062
Asbestine	90	90	90	89	88	87	.....
Barytes	68	67	65	64.5	64	63.5	.....
China clay	63	61	59	57	55	54	.....
Gloss white ($BaSO_4 + Al(OH)_3$)	79	80.5	79.5	78	76	75	.....
Precipitated chalk	87	86	84	82	80	79	.....
Silex	88	88	85	82	80	79	.....
Terra alba	74.5	76	77.5	78	78	78.5	.....
Whiting	71	69	68	67	66	65.5	.....
Carbon-black	0	0	0	0	0	0	.0006
Drop black	16	17	17	15	13	11	.0030
Graphite	26	24.5	23	20.5	19	18	.....
Lamp-black	1.5	1	.7	1	1	1	.0015
Mineral black	7	7	2.5	6.5	6	6	
Magnetic iron oxide (98 per cent.)	12	13	14	14	15	15	.0017

Table I gives the results for the white pigments, inerts, and blacks, and Table II, the results for the colors. The last column in each table gives the thickness at which the pigment is opaque to light of 3655 Å.U.

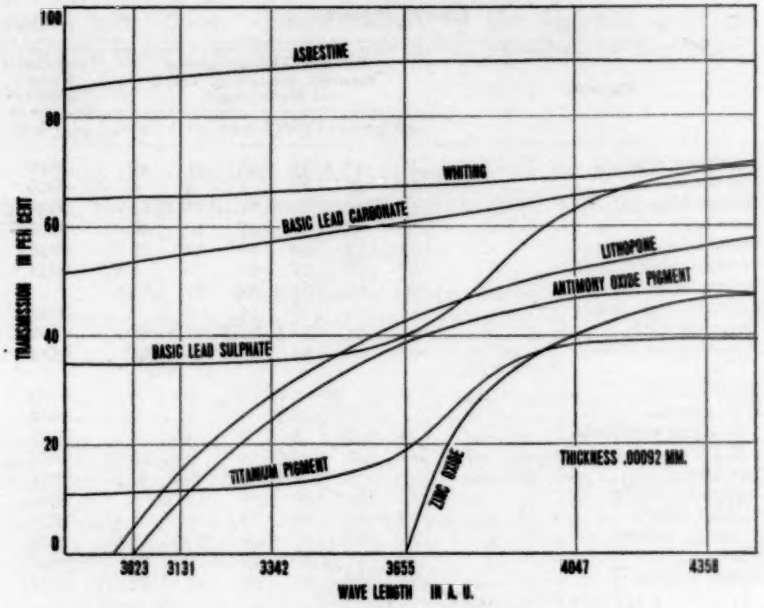
TABLE II.

Colored Pigments.

Pigment.	Per cent. Transmission of Pigment .00092 mm. Thick at Wave-length						Thickness at Which Pigment is Opaque to 3655 Å.U.
	4358	4047	3655	3342	3131	3023	
Aluminum dust	47	46	45	43	41	40	.0070
Blue toner	50	47	22	3	0	0	.0046
Chinese blue	48	39	28	21	16	14	.0046
Iron blue	70	63	57	47	40	36	.0062
Ponsol blue	75	53	49	40	32	27	.0046
Prussian blue	58	36	31	21	10	4.5	.0031
Riviera blue	90	89	87.5	84	82	80.5	—
Sublimed blue lead	9	9	8	4	0	0	.0021
Turquoise blue	93	85	71.5	68.5	68.5	68	.0160
Ultra-marine blue	88	88	85	81	77	75	.0523
Chrome green	2	.5	0	0	0	0	.0009
C. P. green	7	7	5.5	4	2	1	.0022
C. P. green medium	5	6	5	2	1	0	.0022
C. P. green dark	7	7	5.5	4	2	1	.0022
Pine green	5	5	5.5	5.5	6	6.5	.0016
Chromium oxide	13	12	10	10	10.5	11	.0022
Madder lake	15.5	23	20	12	2	0	.0031
American ochre	31	29	27	26.5	26	25.5	.0048
Ochre	40	31	26	26	26	26	.0048
Orange mineral	65	63	55	50	41	38	.0077
Para toner	8.5	9	8.5	7.5	7	6	.0030
Light para toner	52	49	51.5	57	62	64	.0120
Alpha naphthylamine	64	63	57	47	40	36	.0092
Pigment scarlet toner	70	67	62	56	51	47	.0107
Pigment scarlet on gloss white	95	91	82	84	68	66	.0120
Red lead	67	67	65	62	60	59	.0160
Scarlet lead chromate	65	60	57	55	55	55	.0100
Mercuric sulphate	72	71.5	69	66	63	61	.0130
Iron oxide, 37%	50	52	52.5	53	53	53	.0070
Iron oxide, 70%	15	18	19.5	20	20	20	.0027
Iron oxide, 90%	2.5	3.0	3.5	3.0	2.5	2	.0021
Iron oxide, 98%	0	0	.5	0	0	0	.00095
Metallic brown, 50% iron oxide	45	44	42	38.5	36	34.5	.0046
Raw sienna	27	24	23	22	21	20.5	.0032
Burnt sienna	1	.5	.5	.5	1	1	.0016
Cadmium lithopone	17	17	16	14	13	12.5	.0032
Zinc chromate	35	33	32	32	32	31.5	.0030
Chrome yellow	11	13	14	14	14	14	.0022
Medium yellow	3	4.5	6	7	8	8.5	.0015
Raw umber	29	26	24	24	23	23	.0031
Burnt umber	8	8	8	8	8	8	.0019
Zinc dust (blue powder)	63	57	50	46	44	43	.0046

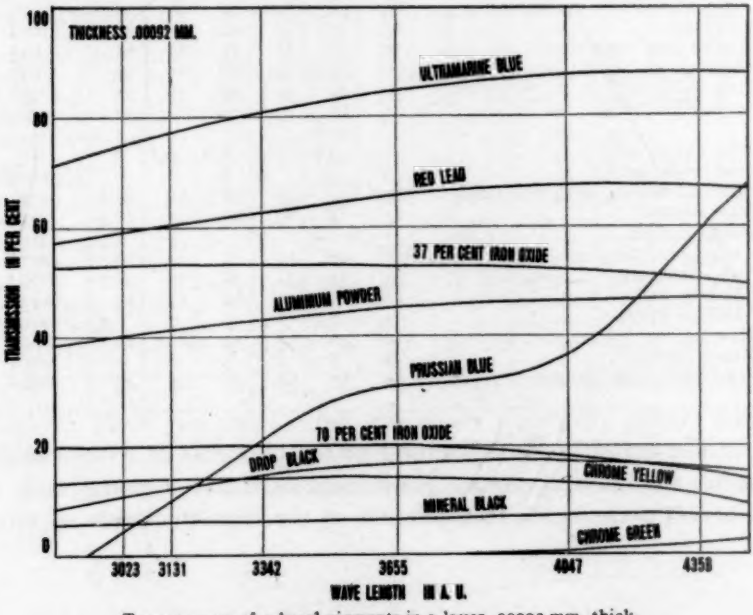
The transmission of several of the pigments at .00092 millimetre thickness is shown graphically in Curve 1 and Curve 2. Curve 3 presents the transmission, at the same thickness, of mix-

CURVE 1.



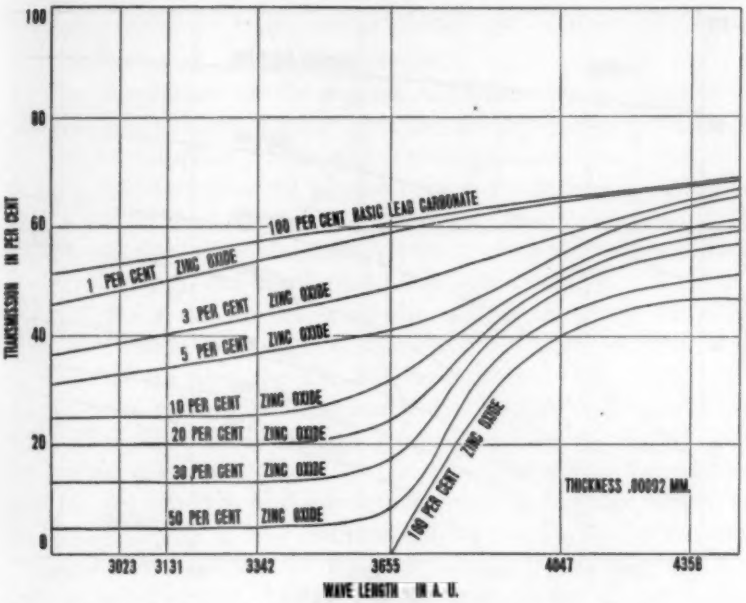
Transparency of white pigments in a layer .00092 mm. thick.

CURVE 2.



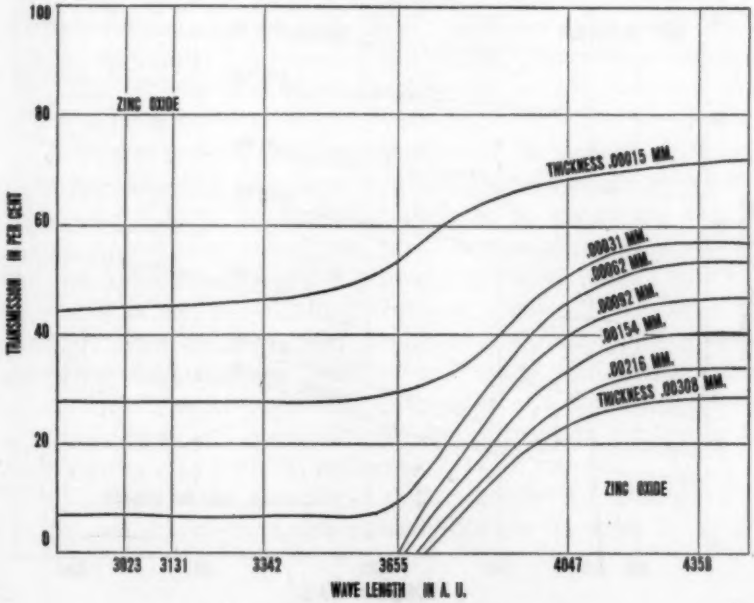
Transparency of colored pigments in a layer .00092 mm. thick.

CURVE 3.



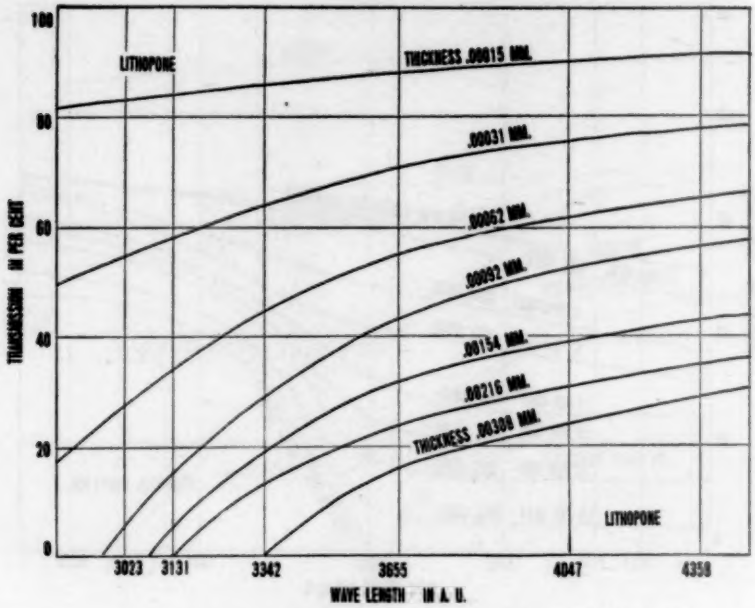
Transparency of mixtures of zinc oxide in basic lead carbonate, pigment layer .00092 mm.

CURVE 4.



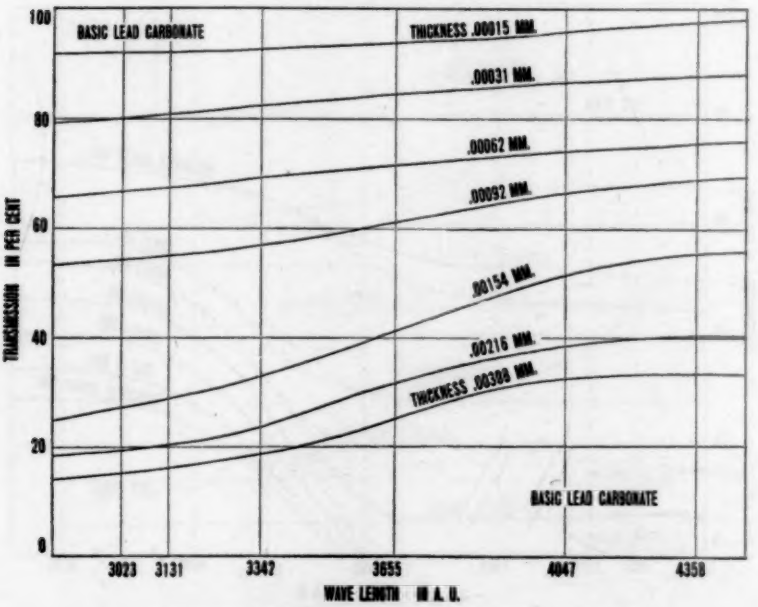
Transparency of zinc oxide at several thicknesses.

CURVE 5.



Transparency of lithopone at several thicknesses.

CURVE 6.



Transparency of basic lead carbonate at several thicknesses.

tures of basic lead carbonate and zinc oxide. Curves 4, 5, and 6 show the transmission of different thicknesses of several pigments.

DISCUSSION.

The absorption of ultra-violet radiations by dry linseed oil and dry nitrocellulose lacquer has been shown in Fig. 2. Linseed oil absorbs completely light of wave-length less than 3700 A.U. and nitrocellulose absorbs almost completely in the same region. As a result of this absorption, a linseed oil film becomes hard and brittle, and then crumbles and powders. A lacquer film behaves in a similar way, but is affected much more rapidly. If there is incorporated in the lacquer or oil film, a pigment which will either absorb or reflect such radiations before they can penetrate into the body of the film, the film will be protected from such radiations. It is recognized that exceptions to this rule may exist. If the ultra-violet radiations accelerate a harmful reaction between the vehicle, and the pigment, or the gas adsorbed on the pigment surface, the surface film of vehicle may be rapidly destroyed. This may expose a new surface subject to further destructive action, or the products of the reaction may penetrate the film with harmful effect. In the general case, however, the energy of the radiations absorbed by the opaque pigment is dissipated as heat, with no harmful effect on the vehicle. Therefore, to test the efficiency of a pigment in protecting a film, it is necessary to measure the amount of ultra-violet radiations transmitted by a definite thickness of pigment. The results presented in Table I and Table II give a relative measure of the efficiencies of the several pigments.

To obtain a more absolute measure of the opacity of a pigment, the thickness necessary to completely absorb or reflect the ultra-violet light is determined. Thus, to be completely opaque to light rays shorter than 3700 A.U., zinc oxide must be .00092 mm., or approximately three pigment particles thick. Carbon-black need be only two-thirds as thick, or .00062 mm. Lithopone, however, must be more than ten times as thick, or .0100 mm. and white lead requires nearly thirty times the thickness, or .0270 mm. The average three-coat paint film is approximately .120 mm. thick and contains sufficient pigment to form a layer from .035 to .045 mm. in thickness.

A measure of the amount of radiation reflected from the pigment, together with the amount transmitted by the same thickness,

indicates whether the pigment is opaque due to its absorbing power, its reflecting power, or both.

Thus, zinc oxide owes its opacity below 3700 Å.U. to its absorbing power, practically no light being reflected. Basic lead carbonate has practically no absorbing power and, therefore, must depend on its reflecting power for opacity. Titanium pigment has a small absorbing power, and, therefore, obtains its opacity by a combination of absorption and reflection.

The two metallic pigments, aluminum dust and zinc dust, must be considered as exceptions to the general rules outlined above. Both show a high transparency in a pigment thickness of .0009 mm. But these pigments have an average particle size of from .004 to .007 mm. Therefore, at pigment thickness of .0009 mm. the pigment layer is considerably less than one particle thick and light passes through the space between the particles. In a layer one pigment particle thick (.004 mm. to .007 mm.) they are entirely opaque to light of all wave-lengths. Also, a piece of aluminum or zinc foil .007 mm. thick is opaque to light of all wave-lengths.

In conclusion, the author wishes to acknowledge the suggestions of Dr. A. H. Pfund, the criticism and help offered by members of the Research Division of the New Jersey Zinc Company, and the assistance of Mr. C. Hall in making the observations.

Measurement of Resistivity of Large Masses of Undisturbed Earth. O. H. GISH and W. J. ROONEY. (*Terrestrial Mag.*, Dec., 1925.)—The Department of Terrestrial Magnetism of the Carnegie Institution investigates earth-currents. A factor in this phenomenon is the electrical resistance of the earth through which they flow.

Four steel rods are driven into the earth in a straight line, the three intervals thus formed being equal. The end terminals are joined to a battery and meter so that a measured current flows from one end to the other. The potential difference between the second and third terminals is obtained from a potentiometer. From the electrical data and the distance between the rods the resistivity of the earth can be computed. The bodies of earth measured varied in length from a yard to a mile, while the resistance of a cubic centimetre ranged from 4000 to 600,000 ohms. Local features, such as a cinder track, declare themselves by rapid changes in resistivity when the line of observation is shifted. The interesting conclusion is reached that "the approximate depth to the water-table, rock strata and such other geological features as involve changes in resistivity can apparently be determined from an analysis of such survey data."

G. F. S.

MARVELS OF SNOWFLAKES AND WATER FORMS.

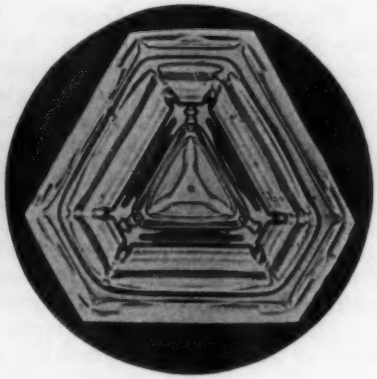
BY

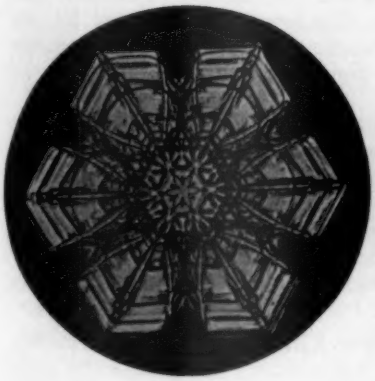
W. A. BENTLEY.

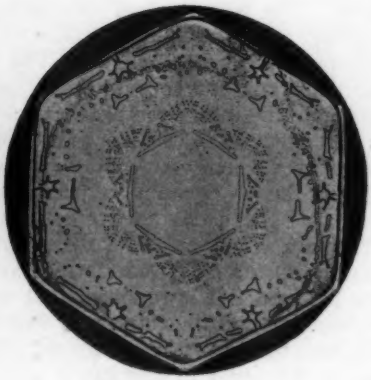
EDITOR'S NOTE: The photographs of snowflakes reproduced in this number of the JOURNAL were taken by Mr. William A. Bentley, of Jericho, Vt., who read before The Franklin Institute an interesting paper on "Marvels of Snowflakes and Water Forms" on April first.

Mr. Bentley has been photographing snow crystals and other water forms for more than forty years. He has in his possession thousands of photographs of water forms, no two of which are exactly alike. The sixteen herein reproduced indicate the amazing variety of forms which snow crystals may assume. Many of these photographs were taken during the recent winter. They therefore represent the latest fashions in snowflakes.

THE EDITOR.







Thermite and Ice Gorges. (U. S. Department of Agriculture Clip Sheet, No. 418, July 5, 1926.)—The first use of thermite in this country to hasten the disintegration of an ice gorge occurred in connection with the great Allegheny River ice gorge at Franklin, Penna., in March of this year, according to a Weather Bureau official stationed at Pittsburgh, Penna., where all the river forecasting for this region is done. Thermite is a chemical compound which, on ignition, quickly reaches a very high temperature. When it is forced into ice the ice is blown apart by the steam produced. It increases in temperature 5000° F. in ten seconds. Its action upon ice was recently discovered by Dr. H. T. Barnes, a Canadian scientist formerly on the staff of McGill University, Montreal.

The ice in the Allegheny River had started to pack during the first week in January near Franklin, and a stretch of fifteen miles was eventually involved, constituting for seventy-four days a continual menace to industries and homes along the river. Property losses were very great. The damage at Oil City was estimated at $500,000, and at Franklin at $100,000. Much of this loss was sustained by the Pennsylvania Railroad Company, whose tracks parallel the gorge throughout its length, and by oil companies through flooding of oil wells.

The inventor of thermite was called upon to undertake to relieve the situation by the use of explosives, both dynamite and thermite. A ton of the latter material was shipped to Oil City and used in almost daily charges at key locations in the ice. Opinions differ as to the effectiveness of thermite compared with natural causes in breaking up the gorge, but the engineers among those who suffered the heaviest losses believe that its use at strategic points greatly hastened the disintegration of the ice. R.

Swiss Have Trouble from Power Lines. (*Scientific Monthly*, July, 1926, p. 67.)—Since the war, Switzerland has practically completed the electrification of its railway system. Nearly every town of any size has its electric tramways and most houses have electric light. The water-power resources are being developed rapidly and current at voltages up to 60,000 is now carried over considerable mileage by overhead cables. The network of wires caused so much induction that it was found necessary to bury all telephone trunk lines and now the interference from the high-power lines, electric railways and tramways is causing great interference for broadcast listeners. Another adverse condition radio has to contend with in Switzerland lies in the topography of the country. High mountains and deep narrow valleys dot Switzerland with "dead" spots. Despite these drawbacks, however, the Swiss are forging ahead with their broadcasting system. Three stations are now in operation and two more are planned. It is reported that vacuum tube receivers are rare, but crystal sets can be counted by the thousands, especially in Zurich and Geneva, centres of broadcasting. The Zurich transmitter is said to be one of the finest in Europe. R.

NOTES FROM THE RESEARCH LABORATORY, EASTMAN KODAK COMPANY.*

THE SPECTRAL SENSITIVITY OF SILVER IODIDE AND OF MIXTURES OF SILVER IODIDE AND SILVER BROMIDE.[1]

By E. Huse and C. E. Meulendyke.

When silver iodide, either in the wet collodion process or in the form of a gelatin emulsion, is exposed in a spectrograph and developed physically, it is found that the material is sensitive only to wave-lengths shorter than 440μμ, and the sensitivity terminates sharply at that point. The existence of this very sharp edge has been used to study the crystal structure of silver bromide emulsions containing mixtures of silver iodide and silver bromide. Thus, an emulsion containing 30 per cent. silver iodide shows no trace of the edge, its spectral sensitivity corresponding to that of silver bromide containing iodide. An emulsion containing 32 per cent. silver iodide, however, shows the edge distinctly, so that it may be assumed that the silver iodide exists as separate crystals in an emulsion containing 32 per cent. This agrees with the results obtained by R. B. Wilsey using X-ray analysis.

High-frequency Rays of Cosmic Origin. R. A. Millikan and I. S. Bowen. (*Phys. Rev.*, April, 1926.)—As a part of their work on the penetrating radiation, which attracted so much interest last fall, the authors felt it desirable to study the rate of discharge of electroscopes at considerable heights above the earth. They therefore designed and had constructed four small recording instruments. Each contained an electroscope with two sputtered quartz fibres. A metal shield protected from static effects. Shadows of the fibres cast by sky light fell on a moving photographic film. A metallic thermometer similarly registered the temperature on a film. On the same film were recorded the readings of a barometer consisting of a closed-arm manometer. All these parts were contained in a cylinder about 7 inches long and less than 3 inches in diameter. The weight of the whole was about 7 ounces. Two balloons weighing 300 grams apiece when empty were used to carry up each apparatus. When filled with hydrogen they had a buoyancy of 550 grams each

* Communicated by the Director.

[1] Communication No. 267 from the Research Laboratories of the Eastman Kodak Company and published in *Phot. J.*, **66**: 306, 1926, and *Sci. Ind. Phot.*, **6M**, 26, 1926.

and rose at the rate of 130 metres a minute. Two balloons were employed so that when one burst, the other could bring the apparatus safely to earth and, that done, could serve to attract attention. Four times an apparatus was sent up from Kelly Field, Tex. Three times the apparatus was returned to the senders from distances of about 80 miles. In two cases a height of more than 11 km. had been reached.

In the higher flight an elevation of 15.5 km. was reached, the total duration of the voyage being three hours and eleven minutes. One balloon burst and the descent began when the temperature was –60° C. The ascent took 115 and the descent 76 minutes. The traces of the positions of the electroscope fibres were sharp and could be accurately measured.

The discharge rate of the electroscope was found to be three times as large at an altitude of 5 km. above the earth as at the surface. Qualitatively this agrees with what had been previously discovered by Gockel, Hess and Kohlhoerster, but the total loss of electricity from the instrument during the two hours it spent at high altitudes was only about one-fourth as much as the Hess-Kohlhoerster curve would have allowed. The lower flight gave similar results. "The results then of the whole Kelly field work constitute definite proof that there exists no radiation of cosmic origin having such characteristics as we had assumed. They show that the ionization increased much less rapidly with altitude than would be the case if it were due to rays from outside the earth having an absorption coefficient of .57 per metre of water."

G. F. S.

The Magnetic and Electric Survey of the Earth. J. A. FLEMING. (*J. Washington Acad. Sciences,* March, 1926.)—This, the address of the retiring president of the Academy, is an authoritative and comprehensive résumé of the work with which he is so well acquainted.

The first step toward a magnetic survey of the earth was taken by Halley, 1698 to 1701, on the Paramour Pink. He it was who devised isomagnetic curves to show the distribution of magnetic elements. At the present time there are about fifty magnetic observatories in operation, twenty of which conduct electrical work. The observatories are by no means uniformly distributed, about twenty being in Europe and only half as many in the entire southern hemisphere. Gauss established the first magnetic observatory in 1832 at Göttingen and aroused so much interest in terrestrial magnetism that soon a system of international coöperation was established and satisfactory instruments for the determination of the magnetic elements were devised. Even to-day in spite of the fine work done by the Department of Terrestrial Magnetism of the Carnegie Institution, there remain half a million square miles, mostly in the Pacific Ocean, where no observations have ever been taken. G. F. S.

NOTES FROM THE U. S. BUREAU OF CHEMISTRY.*

THE RUPP METHOD FOR THE DETECTION OF CHLORINE IN MILK.[1]

By J. T. Keister.

[ABSTRACT.]

AN investigation conducted in the Bureau of Chemistry showed that the Rupp test is not reliable for the detection of added chlorine in milk when the milk contains more than 1 part of copper in 400,000 parts. As fresh milk contains very much less copper than 1 part per 400,000, it may be assumed that the Rupp procedure is admissible for testing a fresh milk for chlorine. In fact, in all the tests made on fresh milks, including bottled market milks, the Rupp test gave negative results. Nevertheless, it is conceivable that under certain conditions bottled milk might take up enough copper to give a positive reaction with the Rupp test. It would seem, therefore, that in case a milk gives the Rupp test, the copper content of the milk should be established in order to avoid an erroneous conclusion as to the presence of added chlorine.

BASIC DYES AS FLOCCULATING AGENTS FOR APPROXIMATE QUANTITATIVE DETERMINATION OF COLLOIDS IN SUGAR-HOUSE LIQUORS.[2]

By M. S. Badollet and H. S. Paine.

[ABSTRACT.]

OF A number of dyes investigated in the Carbohydrate Laboratory of the Bureau of Chemistry, night blue was selected as the most suitable reagent for the approximate quantitative estimation of colloids. This method of estimation is based on the principle of electrical neutralization. It is well suited to sugar factory and refinery control.

The method has been shown to have practical application to cane juice, raw cane sugar, and beet molasses. The limitations

* Communicated by the Chief of the Bureau.

[1] Published in *Amer. J. Pub. Health*, **15**, No. 9, Sept., 1925.

[2] Published in *Internat. Sugar Jour.*, 1926, **28**, pp. 23–28, 97–103, 137–140.

of the method do not interfere with the usual requirements of factory control work.

The use of an ultra-microscope and cataphoresis apparatus, which may be easily constructed at a cost of $30 to $70, or even less, is entirely practicable in the control laboratory.

The dye test may be used to advantage in other industries in which colloids play an important part.

Change in the Surface Tension of Water with the Lapse of Time. F. SCHMIDT and H. STEYER. (*Ann. d. Physik*, 79, No. 5.)—Even as long ago as in 1887 P. Lenard suspected that the tension of a newly formed surface of water grows less during the first instants of its existence. The attempts to prove the existence of such a change were at first without success because a suitable method was not used. In 1913 Hiss applied a fitting procedure and demonstrated a notable decrease in even so short a time as .001 sec. In this paper Hiss' method is improved and extended. At 36° C. and also from 4° to 5° C. no change in the surface tension with the passage of time could be detected. At 18° C. at the instant of the formation of the surface its tension was 9.20 mg./mm. After .00025 sec. the value had fallen to 8.90 mg./mm. and continued to decrease as a dozen subsequent readings were taken. After .0046 sec. it was 7.50 mg./mm. Finally 7.40 mg./mm. was attained as the constant value. Similar results were obtained for a series of other temperatures. For the interval 4° to 36° C. the greatest surface tension is possessed by water at about 12.5° no matter whether the quantity is measured at the moment of formation or at any succeeding time up to .005 sec.

The method gave permanent values of the surface tension that are in agreement with those obtained by others. A similar decrease in tension with time was found to occur with nitrobenzol.

G. F. S.

Mean Intensity of Sound in an Auditorium and Optimum Reverberation. S. LIFSHITZ. (*Phys. Rev.*, May, 1926.)—The concert hall of the State Institute of Musical Science in Moscow seats 120 persons and has a volume of 265 m.^{3}. In this auditorium during a musical performance the number of auditors was changed until the best conditions of reverberation were reached. For different kinds of instrument the times of optimum reverberation were found to be closely the same. For violin, violincello, bass voice and soprano voice the times were all 1.11 sec., while for the piano it was 1.13 sec. and for human speech from 1.08 to 1.14 sec. These results are in agreement with previously determined values. "It is evident that a mean intensity of sound exists which is the same for human speech and musical performances of different kinds, with respect to which our ear determines the optimum impression." G. F. S.

NOTES FROM THE U. S. BUREAU OF MINES.*

COMPUTING THE RATE OF LEAKAGE FROM NATURAL GAS LINES.

By E. L. Rawlins and E. O. Bennett.

VARIOUS methods of making leakage tests have been tried during a study of losses in the transmission of natural gas. This work has been carried on by the Bureau of Mines in coöperation with the Natural Gas Association of America. Results of tests show that the " shut-in pressure-drop " method is the most accurate and reliable; therefore its use is recommended. The gas is " shut in " the line to be tested and is not allowed to escape except through existing leaks. The leakage causes the pressure in the line to fall. The change in pressure is obtained with a dead-weight gage. Approximate results may also be obtained from readings on a good spring test gage. Numerous tests show that the dead-weight gage is more sensitive to small changes in pressure than spring gages.

The temperature of the gas in the line is observed simultaneously with each pressure reading. Temperature changes affect the pressure exerted by a given quantity of gas " shut in " a line, and since the rate of leakage from a closed system is directly proportional to the rate of pressure drop, fluctuations in temperature must be considered.

Two nomographic charts have been prepared, which are arranged to give the leakage rate of gas from lines of various sizes. The charts are intended for ready reference in making field tests, and give a convenient method for quick computation of the leakage losses from lines. A fuller description of the tests, and methods of using the nomographic charts are presented in Serials 2752 and 2751.

TESTS AND CHARACTERISTICS OF DUST RESPIRATORS.

By S. H. Katz, G. W. Smith, and E. G. Meiter.

IN THE Bureau of Mines investigations of respiratory apparatus, a laboratory study of dust respirators has been conducted, and the results will be published in detail as a technical paper.

* Communicated by the Director.

Many industrial dust respirators, and many fabrics and filtering materials were tested. Reference to the patent literature discloses numerous types of dust respirators, mostly based on the filter principle. The present study included only representative filter-type respirators, purchased on the market.

Filtering efficiencies of the respirators were determined by passing air containing either tobacco smoke or suspended silica dust (particles about 1 micron or 0.00004 inch in diameter) through the respirator at rates of 32, 64, or 85 litres per minute. A small stream of the air that escaped from the respirator was viewed in a beam of light in a dark box. An equal stream of the unfiltered air was viewed alongside the first stream, and the unfiltered stream was diluted with measured portions of pure air until the two streams reflected light of equal intensity, in this way a measure of the filtering efficiency of the respirators was obtained. Many filter fabrics were similarly tested by clamping the fabric in a holder which exposed filter areas of 100 square centimetres. The number of plies of filter was varied, and resistance to flow of air was determined both before and after smoke and dust were deposited. Further information on the results of the tests will be found in Serial 2745.

FLOTATION OF LIMESTONE FROM SILICEOUS GANGUE.

By Oscar Lee.

FLOTATION is generally regarded as a process that is only applicable to metallic minerals. However, its scope is now known to be greater than this, because some of the non-metallic minerals are floatable, such as graphite, sulphur, and fluorite. Recent observations show that limestone may be added to the list of floatable non-metallic minerals. Such work is being done on a laboratory scale at the Southern Experiment Station (Tuscaloosa, Ala.) of the Bureau of Mines, Department of Commerce, where experimental magnetic concentration of the low-grade iron ores of the Birmingham district is in progress. Certain experiments have demonstrated that the limestone may be floated from the magnetic log-washer tailing, and then incorporated in the iron concentrate.

If the loss of lime could be prevented, some ores though low in iron and high in insoluble contain enough lime to make their concentrates self-fluxing. Since this loss in the magnetic log-

washer cannot be avoided, the lime must be recovered from the tailing by some method and added to the magnetic iron concentrate before sintering. Then the resulting concentrate will be self-fluxing.

While seeking a suitable means of treating the tailing for recovery of lime, flotation was tried. It was at once evident that this method had possibilities. During the early part of the investigation, soap solution made from a common soap was used as a flotation reagent. The froth obtained was a fairly good lime concentrate. This result was an important clue, and led to tests with the use of such reagents as oleic acid and sodium oleate. Later, cresol, creosote, coal-tar and other similar flotation reagents were tested in combination with the oleic acid and soap solutions. As a result, oleic acid and cresol used together were found to be satisfactory.

The tailing from the magnetic log-washer is in excellent physical condition for flotation. The iron ore had been ground in a ball mill to 100 mesh for magnetic concentration. Hence the bond between the lime carbonate and the other constituents of the tailing was well broken.

Fair results may be obtained by flotation in one stage. However, the work is more efficient when the roughing-and-cleaning system is followed; the tailing from the cleaner is returned to the rougher. Typical results with this system are presented in Serial 2744.

The Principles of the Systematic Application of Geophysical Methods of Prospecting to Mining and Subterranean Engineering. Richard Ambronn. (*Terrestrial Mag.*, March, 1926.)—Until recently the geologist or mining engineer had to be content with what he could find on the surface or at a short distance beneath it. Meanwhile the valuable deposits near the surface have been worked until search needs to be made for others to replace them as exhaustion approaches. The deeper the latter are the more expensive it is to open them and in consequence the more important it is to be sure of them before operations are begun. Thus during the past decades attempts have been made to detect the presence and to determine the structure of economically valuable strata through some action which they exert at a distance. Fortunately some deposits do manifest their presence by effects which they produce. Thus in Sweden toward 1850 magnetic measurements were employed to locate magnetic iron ore. Good results were sometimes secured but this was not always the case. These early attempts were handi-

capped by the limited knowledge of those who made them. More recently a fortunate coöperation has grown up between geology, on the one hand, and geophysics on the other.

Applied geophysics has two chief groups of methods. "In the first of these two groups we may place the processes based on the physical properties of those elements of the subsurface strata which are able to exert direct action at a distance. This category includes the force of gravity, the magnetic fields, and the radio-active radiations and emanations. It further includes the action of the electric potential-differences between chemically different subsurface formations, or between such formations in themselves uniform but exposed to different local chemical actions." The second group consists of processes wherein the substratum influences in some way the production or the transmission of energy in the earth, the electric, thermal, geo-elastic and electrodynamic methods of investigation.

Prospecting for oil is a good instance of the application of the methods mentioned. That this has become of importance is shown by the departure of three men from the staff of the Bureau of Standards to take up such work.

The warning is given that to a known distribution of quantities on the surface of the earth there may be several possible distributions of causes in the substrata, any one of which is competent to account for what is observed on the surface. The selection of the real cause of the surface effects is often facilitated by limitations due to geological considerations. "In Texas, for instance, a stratum of especially good conductivity at a depth of some hundred metres could only signify porous strata permeated with highly concentrated salt water. In the mining districts, on the other hand, a mass of equal conductivity would have to be interpreted as indicating ore. In Texas a mass lacking in electric conductivity might be a salt mass or dry lime or perhaps an oil deposit. Its exact nature can only be ascertained by exact measurements of the density and magnetic properties of the mass, or of the speed of acoustic vibration possible within it."

G. F. S.

Isotopes and Atomic Weight of Lead.—THEODORE W. RICHARDS, HAROLD S. KING, and LAWRENCE P. HALL, of Harvard University (*Jour. Am. Chem. Soc.*, 1926, **48**, 1530–1543), attempted to separate ordinary lead into its supposed isotopes by the process of irreversible volatilization and by the Grignard process through conversion into tetraphenyl lead. Density methods were found not sufficiently accurate to prove any possible separation into isotopes. Each fraction was converted into lead chloride, which was then used for the determination of the atomic weight of lead by measurement of the ratio of lead chloride to silver. The results of these determinations showed that the separation attained was not greater than the possible error of experimentation. The value of the atomic weight of ordinary lead obtained in this research was 207.217.

J. S. H.

THE FRANKLIN INSTITUTE.

COMMITTEE ON SCIENCE AND THE ARTS.

(Abstract of Proceedings of Stated Meeting held Wednesday, June 2, 1926.)

HALL OF THE COMMITTEE,
PHILADELPHIA, June 2, 1926.

MR. CLARENCE A. HALL, *Chairman.*

The following reports were presented for final action:

No. 2853: Coolidge X-ray Tube.

This report, recommending the award of the Howard N. Potts Medal to Dr. William D. Coolidge, of Schenectady, N. Y., in consideration of the originality and ingenuity shown in the development of a vacuum tube that has simplified and revolutionized the production of X-rays, was adopted.

No. 2855: The Fuller-Kinyon Conveying System.

This report, recommending the award of the Edward Longstreth Medal to Mr. Alonzo G. Kinyon, of Fullerton, Penna., in consideration of new and important improvements in the art of conveying pulverized materials, was adopted.

The following report was presented for first reading:

No. 2854: Shockless Jarring Machine.

GEO. A. HOADLEY,
Secretary to Committee.

MEMBERSHIP NOTES.

ELECTIONS TO MEMBERSHIP.

(Stated Meeting, Board of Managers, June 9, 1926.)

NON-RESIDENT LIFE.

MR. ALFRED L. LOOMIS, Banker, 25 Nassau Street, New York City, N. Y. For mailing: Tuxedo Park, N. Y.

RESIDENT.

MR. ROBERT ANDERSEN, Teacher, The Episcopal Academy. For mailing: 35 West LaCrosse Avenue, Lansdowne, Penna.

MR. GEORGE I. BODINE, JR., Banking, 816 Packard Building. For mailing: 118 Pelham Road, Mount Airy, Philadelphia, Penna.

MR. CONRAD HENRY BOLEY, Research Chemist, 3729 North Sixth Street. For mailing: 3726 North Randolph Street, Philadelphia, Penna.

MR. WALTER H. DILKS, 8201 St. Martin's Lane, Chestnut Hill, Philadelphia, Penna. For mailing: 521 Commercial Trust Building, Philadelphia, Penna.

MR. WILLIAM G. LITTLETON, Vice-president, Fidelity Trust Company, 303 Llandrillo Road, Cynwyd, Penna. For mailing: 325 Chestnut Street, Philadelphia, Penna.

MR. WILLIAM CLARKE MASON, Attorney-at-law, 8233 Seminole Avenue, Chestnut Hill, Philadelphia, Penna. For mailing: 934 Land Title Building, Philadelphia, Penna.

NON-RESIDENT.

MR. HOWARD ECKER, Chemist, R. F. Johnston Paint Company. For mailing: 1510 Dana Avenue, Cincinnati, Ohio.

DR. DAVID BARKER RUSHMORE, Consulting Electrical Engineer, University Club, 1 West Fifty-fourth Street, New York City, N. Y.

MR. GEORGE W. SMITH, JR., Technical Assistant to Vice-president and General Manager, White Motor Company, 10,602 Lake Shore Boulevard, Cleveland, Ohio. For mailing: White Motor Company, Cleveland, Ohio.

CHANGES OF ADDRESS.

MR. FRANK GITTLESON, Mt. Washington, Baltimore, Md.

MR. HAROLD GOODWIN, JR., 3927 Locust Street, Philadelphia, Penna.

MR. RICHARD C. MCCALL, 2115 Locust Street, Philadelphia, Penna.

MR. E. B. PATTERSON, 121 East Rogers Avenue, Merchantville, N. J.

DR. SAMUEL E. POND, Marine Biological Laboratory, Woods Hole, Mass.

MR. BENJAMIN WILEY SANDS, 324 Fifth Street, S.E., Washington, D. C.

NECROLOGY.

Mr. Alexander Brown Coxe, Paoli, Penna.

BOOK REVIEWS.

INTRODUCTION TO THEORETICAL PHYSICS. By Arthur Haas, Ph.D., Professor of Physics in the University of Vienna. Translated from the third and fourth editions by T. Verschoyle, M.C., B.Sc., A.R.C.S., with a foreword by Prof. F. G. Donnan, F.R.S. Cloth, 8½ × 5½ inches. Vol. I, xv–331 pages. Vol. II, xi–414 pages. New York, D. Van Nostrand Company, 1925–1926. Price, $6 per volume.

Throughout the history of physical science until modern times, numerous changes of view on natural phenomena are recorded. As knowledge of the relation between these phenomena became more precise, from an increasing dissemination of this knowledge and the correspondingly improved facilities for further advances resulting therefrom, physical science appeared to have arrived within measurable distance of the ideal of a firmly established deductive basis. These very advances, however, have brought about the disclosure of new facts which have proved beyond the reach of already seemingly well-established concepts of physics. There are innumerable contributions on these profound analyses of modern times and it is a difficult matter for a student to determine to what extent they are related to the physics of modern conventional treatises or how far they are based upon considerations which are not postulated in such treatises.

The present work is especially illuminating in this regard. The author's object is to provide a complete survey of the present state of theoretical physics

in combining as far as possible modern physics with the developments of present-day advances into one united whole. A sharp line of demarcation is made in the subject-matter of the two volumes. In the first, only relations which can be derived independently of atomic hypotheses are treated, while in the second, the deductions are made from a consideration of atomic structure. The mathematical treatment is especially notable. Vector analysis is employed throughout with unvarying consistency. This mode of analysis possesses the advantage of a uniform system which permits a simplification of many derivations and avoids superfluous repetitions of analogous processes of thought in different branches of physics. To the student unaccustomed to the vector method it is somewhat like learning a new language, and the question may properly be raised whether the mathematical elegance of a uniform adherence to the vector system is not attained at the expense of desirable simplicity. The author has anticipated this difficulty by providing a full and lucid account of this method which, it may be noted, has come into extensive use in recent years. These matters of purely mathematical character are collected in separate sections in a quite general and abstract form in order to avoid interrupting real physical processes of thought by the discussion of purely mathematical considerations.

Volume I is in two main divisions, Part I, Mechanics, and Part II, Theory of the Magnetic Field and Light. Volume II contains the new territory: Part III, Atomic Theory; Part IV, Theory of Heat; Part V, Theory of Relativity. In the older text-books, "sound" is an important topic and in this work it is not mentioned as such, though the chapter on the general theory of vibrations and of waves in Part I contains a highly detailed but abstract account of vibrations. Doubtless the lack of fundamental character of its development justifies its omission in a "theoretical introduction." Part II includes Maxwell's theory of the electromagnetic field and in the discussion of the theory of light, its electromagnetic nature is constantly pointed out. Under Atomic Theory of Part III a full account is given of the quantum principle. Then the theory of the hydrogen atom which includes an explanation of the Bohr atom and Sommerfeld's theory of electrical orbits, and their relation to spectral phenomena. This is followed by a discussion of Röntgen rays in which space-lattices and the work of Laue and the Braggs are given prominence. The theory of the elements occupies the next chapter. A chapter on general theory of spectra and atomic structure completes Part III. This matter, which occupies half the volume, represents a condensed account of those fruitful researches of modern times that have brought about the profound changes which in recent years views on natural phenomena have undergone.

In dealing with Heat and Thermodynamics in Part IV, the basis of pure statistics in as general a form as possible has been adopted as the only one which "... can combine the theory of heat with the unitary system of modern physics ..." Special Theory of Relativity and Theory of Gravitation are discussed at considerable length in Part V.

In stating that only the principal rules of the calculus are premised on the part of the reader and that he may be a "beginner, as is often the case in the reading of text-books," the author gives the impression that no considerable amount of mathematical training is requisite, but certainly only a person with

sound, if not diversified, mathematical training could reasonably be expected to follow the author's argument.

The work is unique in presenting in didactic form the whole structure of physical theory as it exists to-day. LUCIEN E. PICOLET.

STEAM CONDENSING PLANT IN THEORY AND PRACTICE. By James Sim, B.Sc.Eng. (Lond.), Chief Designer, Condenser Department, Messrs. G. and J. Weir, Ltd., Engineers, Cathcart, Glasgow. xiii–271 pages, 9½ × 6½ inches, cloth. New York, D. Van Nostrand Company, 1925. Price, $6.50.

In marine practice, the condensing engine is the invariable rule, except for tugs and other like small harbor vessels. Condensing stationary engines were formerly restricted to localities of ample water-supply and many stationary power-plants of considerable size were thus obliged to operate non-condensing. The advent of the evaporative condenser, however, has made it possible to operate stationary engines with a consumption of water only two-thirds that condensed from the exhaust. Electric power and the gas engine have monopolized the field of small plants. Modern steam power-plants are therefore generally of considerable size and condensing, and the condensing system ranks in importance with the engine itself, particularly in turbine-equipped plants where high vacua are demanded for proper economy. The condensing system should accordingly receive a searching analysis in the arrangement and proportioning of its component parts.

This specification is adequately met in the work at hand. The author states his aim has been to provide students with rational methods for the design of the steam condensing plant which may also be useful to engineers engaged in the design or operation of such plant. There are twelve chapters as follows: I, Surface Condensers; II, Low-level Jet Condensers; III, High-level (Barometric) Jet Condensers; IV, Ejector Condensers; V, Evaporative Condensers; VI, Air Ejectors and Air Pumps; VII, Water-extraction Pumps; VIII, Circulating Pumps; IX, Evaporators; X, Surface Feed Water Heaters; XI, Feed Systems; XII, Deaëration Plants.

The first chapter, which occupies seventy-five pages, before proceeding with the specific features of surface condensers, takes up such fundamentals as heat-flow through tube walls, Dalton's law of partial pressures, quantity of cooling water, possible vacuum and other necessary principles to the process of rational design. These are formulated at length with the steps of the algebraic operations given quite fully, a feature which is maintained throughout the work. The details of the quantities and sizes entering into the design of a surface condenser are derived by sound and practical methods. Then an example is fully worked out on the determination of the principal dimensions of a condenser for given conditions with a dozen minor problems of illustrative value. The chapter ends with descriptions of several makes of surface condensers and the results of a test and analysis of performance of a 10,000-kw. condensing plant. About one-third of the volume is taken up by this chapter.

The next two chapters give an account of low-level and barometric condenser design in which the methods of determining quantities and sizes are adequately considered. The fourth chapter considers the ingenious and compact Korting ejector condenser. The theory of the evaporative condenser is clearly

given in chapter five and one form of this type is described in detail. In view of the wide adoption of this recent form of condensing plant some amplification of this chapter would not be amiss.

Piston pumps have been all but supplanted in condenser practice by the ejector, the Leblanc impeller-ejector for the removal of condensate and air, and by the centrifugal pump for circulating water and also for the condensate with an independent ejector for removing air. All of these devices receive adequate analysis, as to general principles, application and determination of sizes. The old style air-pump is not entirely ignored, however. One style, the Edwards, is described as advanced practice of the old school. The value of a bibliography in a work of this sort is generally conceded and its absence is a notable omission. The highly detailed analysis of the subject with the very clear explanations which the author has made cannot fail to be of the greatest value to engineers and students. LUCIEN E. PICOLET.

RELAY HANDBOOK, prepared by the Relay Subcommittee, Electrical Apparatus Committee, Technical National Section, National Electric Light Association, with the coöperation of the Relay Subcommittee, Protective Devices Committee, American Institute of Electrical Engineers. C. H. Sanderson, New York Edison Company, Editor-in-chief. xii–1001 pages, 6½ × 4½ inches, flexible fabricoid. Published by the National Electric Light Association, New York City, 1926.

Only a few decades ago the term "relay" in its electrical sense suggested the little instrument used in telegraphy whereby the current from a local battery is released by feeble impulses of the line current to produce distinctly audible signals. The art of telegraphy has rather persistently adhered to this well-proved device with little change of form, but we must accustom ourselves to an amplification of the term. Modern development in the field of electric power generation and transmission has given rise to a wide variety of forms of relays for many different purposes in that field.

The capacity of generating stations has greatly increased in recent times and, with it, there has followed a corresponding increase in size of generating units and of transformer stations and equipment as well. The necessity for the automatic protection of the operative components of these installations has kept pace not alone with the magnitude of power developed, but also with the increasing complexity of the circuits served, and a variety of types of relays and protective systems covering every contingency within the foresight of technical acumen has been developed and commercially standardized.

The Relay Handbook is designed to present in one compact volume all available information on the subject. Its nine sections are contributed by eleven collaborators, each of whom is identified with an important electric-power industry, under the editorial supervision of Mr. C. H. Sanderson, of the New York Edison Company, who is also one of the joint-authors. About one-half of the volume is occupied by detailed descriptions of principal types of relays, which is preceded by a collection of general data and definitions. An almost bewildering variety of current-control devices is there described and illustrated. The description of each separate apparatus is given in accordance with a uniform well-chosen plan which insures precision in the specifications.

Accompanying these descriptions are one or more general views of the apparatus with labeled lead-lines to the important operative elements and diagrams of connections and graphs of operative characteristics. This section includes a comprehensive table of each piece of apparatus which displays its purpose, method of operation, rating and the page number of its description. The same exhaustive treatment characterizes the remaining sections. These sections deal, respectively, with trip-mechanisms, details of d.c. system protection, details of a.c. system protection, relay transformers, test and maintenance, and short-circuit calculations. These divisions are very fully illustrated. Finally the valuable features of an unusually copious bibliography and an adequate index of subject-matter are provided.

Every effort, the authors state, has been made to include the relays of all manufacturers and to accord to each alike impartial presentation. The power-plant designer relies, for auxiliary equipment, upon commercially developed apparatus. In choosing relay equipment, he will find in this work a source of comprehensive and authoritative information. Its obvious value to the designer suggests compilations, on the same plan, of other standardized power-plant equipment.

LUCIEN E. PICOLET.

THE PRINCIPLES OF PHYSICAL OPTICS, an historical and philosophical treatment. By Ernst Mach, translated by John S. Anderson, M.A., D.Sc., Ph.D., and A. F. A. Young, B.Sc., Ph.D. xi–324 pages, 8½ × 5½ inches, cloth. New York, E. P. Dutton and Company. Price, $6.

Recent developments in physical science, the formulation of which does not harmonize with established concepts, have made a close scrutiny of the fundamentals of the science a matter of the deepest interest. The appearance of an authoritative work in which optical hypotheses are surveyed from their earliest conceptions to their evolution into modern established theorems is therefore of inestimable value to the serious student. By presenting in easily available form how ideas concerning the nature of light have been gradually moulded into modern concepts, this work will spare the student much time, and doubtless not a little fruitless labor, in relieving him of the search through voluminous original works which moreover are not to be found in every scientific library.

The absence of an account of the "new physics" of radiation and the relativity theory will perhaps prove disappointing. The inclusion of these matters, the author states, has been delayed by the adverse circumstances of 1916 when the original work was published, and must be reserved for another still uncompleted volume. Notwithstanding the omission of these important topics, the reader will derive much satisfaction from a study of the distinguished author's scholarly and analytical account of the growth of physical optics from ancient times to the beginning of the present century.

LUCIEN E. PICOLET.

LES NOUVEAUX AXIOMES DE L'ÉLECTRONIQUE (MÉCANIQUE DES ÉLECTRONS). Par R. Ferrier, Ingénieur des Ponts et Chaussées. 63 pages, 8½ × 5½ inches, paper. Paris, A. Blanchard, 1925. Price, 3 francs.

A more or less general belief has prevailed until latterly that quantitative changes in physical processes take place with mathematical continuity. Present-day experimental evidence is at variance with this idea of energy variations

and the question has been under the most searching investigation in every land. The present essay is a contribution in this field of research in which the author aims to reconcile the classic system of electrodynamics with quantified energy.

The work is a collection of three lectures before the Société française de Physique which were subsequently published in the Revue Générale de l'Électricité. An expression for the energy of a system of electrons in an absolute void is first established. Then considering the ether composed of electrons, their constituents are shown to be in equilibrium as a whole. Upon this groundwork a number of deductions of electrical theorems and laws of radiation are made. Vectorial analysis is freely used with the notations peculiar to this method of space-analysis of which a synopsis is given in an appendix. These essays should prove of rare interest to all who are occupied with recent developments in fundamental physical theory. LUCIEN E. PICOLET.

NATIONAL ADVISORY COMMITTEE FOR AERONAUTICS. Report No. 229, Pressure Distribution over Thick Tapered Airfoils, N.A.C.A. 81, U.S.A. 27 C Modified, and U.S.A. 35. By Elliott G. Reid. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, ten cents.

At the request of the United States Army Air Service, the tests reported herein were conducted in the 5-foot atmospheric wind-tunnel of the Langley Memorial Aeronautical Laboratory. The object was the measurement of pressures over three representative thick, tapered airfoils which are being used on existing or forthcoming Army airplanes. The results are presented in the form of pressure maps, cross-span load and normal force coefficient curves and load contours.

The pressure distribution along the chord was found very similar to that for thin wings, but with a tendency toward greater negative pressures. The characteristics of the loading across the span of the U.S.A. 27 C modified are inferior to those of the other two wings; in the latter, the distribution is almost exactly elliptical throughout the usual range of flying angles.

The form of tip incorporated in these models is not completely satisfactory and a modification is recommended.

Report No. 233, The Aerodynamic Characteristics of Seven Frequently Used Wing Sections at Full Reynolds Number. By Max M. Munk and Elton W. Miller. 16 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, ten cents.

This report contains the aerodynamic properties of the wing sections U.S.A. 5, U.S.A. 27, U.S.A. 35 A, U.S.A. 35 B, Clark Y, R.A.F. 15, and Göttingen 387, as determined at various Reynolds Numbers up to an approximately full-scale value in the variable density wind-tunnel of the National Advisory Committee for Aeronautics.

It is shown that the characteristics of the wings investigated are affected greatly and in a somewhat erratic manner by variation of the Reynolds Number. In general there is a small increase in maximum lift and an appreciable decrease in drag at all lifts.

Report No. 234, Three Methods of Calculating Range and Endurance of

Airplanes. By Walter S. Diehl. 18 pages, illustrations, quarto. Washington, Government Printing Office, 1926. Price, ten cents.

This report, which was prepared for the Committee, develops new equations which give the range and endurance of airplanes with accuracy equal to that obtained from a step-by-step integration of the flight. A method of obtaining equally satisfactory results from Breguet's equations is also given in detail. A third method of calculating range and endurance, derived by the writer for use in routine estimating in the Bureau of Aeronautics, is also given in full.

This report contains tables and curves arranged for convenient use and illustrates the three methods by comparative estimates.

MELLON INSTITUTE OF INDUSTRIAL RESEARCH OF THE UNIVERSITY OF PITTSBURGH. Bibliographic Series, Fourth Supplement to Bulletin No. 1, A List of the Bulletins, Journal Contributions, and Patents by Members of Mellon Institute of Industrial Research during the calendar year 1925. Manuscript, 11 pages, quarto, Pittsburgh, Penna., Institute, 1926. This list includes all contributions to literature (pamphlets and magazine articles) by the several members of the Institute as well as a record of the patents issued to them in the United States, Belgium, Great Britain, Canada, France and Germany during the year 1925.

Copies of the list may be had on application to the Institute.

PUBLICATIONS RECEIVED.

Canada Department of Mines, Mines Branch. Investigations of Fuels and Fuel Testing, 1924. 81 pages, illustrations, plates, 8vo. Investigations of Mineral Resources and the Mining Industry, 1924. 118 pages, illustrations, plates, 8vo. Investigations in Ore Dressing and Metallurgy, 1924. 115 pages, illustrations, 8vo. Ottawa, King's Printer, 1926.

Ontario Department of Mines. Bulletin No. 56, District of Patricia, Red Lake and Adjacent Territory, by W. R. Rogers. 11 pages, map, 8vo. Toronto, King's Printer, 1926.

National Advisory Committee for Aeronautics: Technical Notes, No. 237, Propeller Design. A Simple System Based on Model Propeller Test Data—III, by F. E. Weick. 19 pages, diagrams, tables, quarto. No. 238, Propeller Design. A Simple Method for Determining the Strength of Propellers—IV, by F. E. Weick. 11 pages, diagrams, tables, quarto. Washington, Committee, 1926.

U. S. Bureau of Standards: Technologic Paper, No. 313, Some Characteristics of Quenching Curves. 23 pages, diagrams, 8vo. Price, ten cents. Miscellaneous Publication No. 73, Subject Index of United States Government Master Specifications. 5 pages, 8vo. Price, five cents. Washington, Government Printing Office, 1926.

U. S. Department of Commerce, Bureau of Mines. Statement of Hon. Herbert Hoover at Hearing before the Committee on Interstate and Foreign Commerce, H. of R., Sixty-ninth Congress, First Session, on Coal Legislation. 18 pages, 8vo. Washington, Government Printing Office.

CURRENT TOPICS.

The Nature of Light. GILBERT N. LEWIS. (*Proc. Nat. Acad. Sci.*, Jan., 1926.) **Space, Time and the Universe.** J. H. JEANS. (*Nature*, Feb. 27, 1926.)—It is well known that the nature of light is at the present time not understood. A few years ago the primacy of the undulatory theory was undisputed, but it is now recognized that all the phenomena of light cannot be explained by this theory. The quantum theory has come to the fore to account for what the older theory cannot make clear and a reconciliation or combination of the two theories is sought. In the quest, Sir J. J. Thomson himself was engaged, but up to the present day it is impossible to say that the result has been accepted as satisfactory. In order to comprehend the difficulties of the task the reader might well study the "Nature of Light," in which Gilbert N. Lewis, University of California, states certain conclusions to which he has been led. "The following views regarding the mode of transmission of light are of so unorthodox a character that I set them down with some reluctance, but it seems to be generally admitted that the paradox of quantum theory cannot be resolved without doing violence to one or more of our common notions. Some of the consequences of the theory I am going to advance are repugnant to common sense, yet searching in vain for an alternative and finding no physical fact of optics or thermodynamics in opposition to the theory, I have come to regard it as a natural and indeed inevitable extension of Einstein's principle of relativity."

A source of light in front of two slits is considered. If one slit alone is open, light reaches a certain point of a screen beyond the slit. If, on the other hand, both slits are open, a series of interference fringes is formed on the screen and in general the point that previously received light will no longer receive it. This offers no difficulty to the undulatory theory, but it is hard to make the quantum theory give an explanation of what occurs. "So far our analysis has merely shown that no explanation so far proposed explains at the same time the phenomena of quanta and of interference." In the study of the interference system above described he says, "There constantly recurs to us the hardly credible thought that in some manner the atom in the source S can foretell before it emits its quantum of light whether one or both of the slits are going to be open. Although it sounds absurd, this, in a certain sense, is the theory I am going to propose. It is generally assumed that a radiating body emits light in every direction, regardless of whether there are near or distant objects which may ultimately absorb that light; in other words, that it radiates 'into space.' This assumption has seemed natural and convenient. I am going to make the contrary assumption that an atom never emits light except to another atom, and

to claim that it is as absurd to think of light emitted by one atom regardless of the existence of a receiving atom as it would be to think of an atom absorbing light without the existence of light to be absorbed. I propose to eliminate the idea of mere emission of light and substitute the idea of transmission, or a process of exchange of energy between two definite atoms or molecules, so that we can no longer regard one atom as an active agent and the other as an accidental and passive recipient, but both atoms must play coördinate and symmetrical parts in the process of exchange. I shall not attempt to conceal the conflict between these views and common sense. The light from a distant star is absorbed, let us say, by a molecule of chlorophyl which has recently been produced in a living plant. We say that the light from the star was on its way toward us a thousand years ago. What rapport can there be between the emitting source and this newly made molecule of chlorophyl? Suppose we make this same star the source of light in the apparatus of figure 1 (the apparatus with the two slits). By opening the second slit we prevent a particle of light from reaching the point *C*. Do we therefore prevent its original emission? If so, it would mean that we could, perhaps in a trivial way, but nevertheless in principle, alter the course of past events. Such an idea is repugnant to all our ideas of casualty and temporal sequence; but we must remember that these notions have arisen from the observations of complex processes which are very different from the elementary reversible processes which we are here considering. Unless the result of some actual fact of experiment or observation can be brought against the new view, we need not be deterred by this conflict with common notions."

Later in his paper Professor Lewis raises the question whether the theory advanced by him can predict some phenomenon that may be looked for. He accordingly devises a crucial experiment wherein a suspended mirror by his theory should turn under the action of incident light, whereas it should by the classical theory show no such tendency. It is much to be hoped that this test be made. Should such a passive mirror really revolve about its axis ever so little, the philosophical consequences will rival the deductions drawn from the fall of Newton's famous apple.

On February 12, 1926, the gold medal of the Royal Astronomical Society was awarded to Albert Einstein for his work on relativity and gravitation. On this occasion the president of the society, J. H. Jeans, who is also secretary of the Royal Society, delivered a notable address. The main contributions of Einstein to scientific thought fall under the headings of relativity and quantum theory. Speaking of his work in the former domain the president said, "By his single 1905 paper, Einstein started a revolution in scientific thought to which as yet we can see no end, to which, indeed, we can scarcely yet imagine any end. Had he written only that one paper, his position as one of the great figures of science would, in my opinion, have been secure. Time and space, as separate entities,

the time and space we wrote about and thought about previous to 1905, have gone, or, as Minkowski puts it, have become shadows, while only the product of the two remains as the framework in which all material phenomena take place." How great a change is upon us the following quotation will show: "In the twentieth century the majority of men believe that there is a sort of flow of time which is regulated by our consciousness. We live now in the year 1926, and therefore speak of 1925 as dead and past; 1927 is not yet born, but will spring into life for us just as soon as we need it, which will be when we reach the end of 1926. So the traveller journeying west through Devon might suppose that Somerset had fallen out of existence at the moment he left it, and that Cornwall was waiting only for his arrival to come into existence. Foolish, perhaps, when expressed in terms of space and yet our everyday belief in respect of time. Einstein's theory eliminates the supposed essential difference between space and time; what is one man's space is another man's time. Not only so, but what is the past in time for one man is the future for another man. According to the view thrust upon us by the theory of relativity, the space-time landscape does not spring into life in front of us and die behind us; it is unalterably there. Existence becomes a picture rather than a drama, and the year 1927 has the same sort of existence as the county of Cornwall. Does the theory, however, leave room for us to go further? Does it leave room for life and consciousness, and for the attributes, such as free-will, which we attach to them? The materialistic philosophy of a generation ago used to insist that the picture which science then presented of the universe left no room for such things. That picture has no doubt been torn to shreds, but what about the new picture? Does this look with any more favour on our instinctive belief that we can guide our actions and make the universe in some small degree different by our presence? Or are we mere passive spectators, carried—in a train the speed of which we cannot regulate and the course of which we cannot alter by an inch—out of a Devon with which we can do nothing except gaze at through a window, into a Cornwall which is already in existence and has been alterably created by other hands than ours? To this last question the answer of the theory of relativity would seem to be in the affirmative, but relativity is not the whole of natural science; it is not even the whole of Einstein's work." What he has done in the theory of quanta "may contain the needed antidote to the determinism and automatism" to which the bare theory of relativity might consign us.

Einstein has transformed still another category of thought according to Jeans. "It seems as though the deadly inevitability of cause and effect has ended, and we are in the presence of new possibilities of freedom which as yet we do not understand." If this be true, it quite overshadows Einstein's overthrow of Newton's dynamical explanation of gravitational force and his substitution of the conception that gravitation is a property of space.

Before we accept as our own the iconoclastic consequences of the theory of relativity we should keep in mind that the experiments of Dayton C. Miller (published in *Science*, April 30, 1926) are in opposition to the theory. G. F. S.

The Expansion of Sound in the Atmosphere. E. WIECHERT, Göttingen. (*Meteorologische Zeit.*, March, 1926.)—During the recent war unusual opportunities were afforded for the hearing of loud sounds at great distances from their source and more recently the planned destruction of munitions has made possible the study of the manner in which sound waves spread from their origin.

When an explosion occurs and its effect is detected by the human ear, there is a zone of silence which separates the outer from the inner region of audibility. The adjective "abnormal" is applied to the outer region, while the inner region is called "normal." In exceptional cases the outer region appears as a ring enclosing the source of sound on all sides. Generally, however, only a sector or disconnected bits of the ring appear. Sometimes the inner and outer regions are joined by a Polish corridor. There is no doubt significance in the fact that, when a zone of silence exists at all, its outer boundaries are from 100 to 200 km. from the source. If an auditor should be transported instantaneously from a place on the inner boundary of the outer region of audibility to a point twice as far distant from the source he would usually find that he could no longer hear the sound. Angenheister's compilation of recent observations places the difference between "normal" and "abnormal" propagation in a new light. From the emphasis laid upon the determination of the speed of travel of the waves from explosions, he finds that the normal waves proceed with a speed close to that with which sound waves travel along the surface of the earth, about 331 m. per sec., while abnormal waves on the contrary possess a slower velocity generally ranging from 280 to 300 m. per sec.

The limits and extension of the two regions are somewhat dependent on the wave-length of the sound, for normal waves of such considerable length that they must be registered by instruments because they cannot be heard are recorded at distances from the source proper for abnormal waves. There are still further complications in the separation of the two types of waves.

Now how are these anomalies to be explained? The apparently lessened speed of the abnormal waves is obtained by dividing the distance along the earth from source to point of observation by the time elapsing from start to arrival. The smallness of this quotient may be due to the wave rising to a considerable height and later turning down to the abnormal region. Von der Borne attributed such a change of path to the presence of hydrogen in the upper atmosphere. Serious objections were urged against this view. Some held that the cause lay in the distribution of temperature and wind velocity in the atmosphere and especially in the troposphere (that part

of the atmosphere in which the temperature decreases with elevation and in which convection currents are prevalent). The author develops a theory to account for the rise of a sound wave into high regions and its subsequent deflection downward. He finds it possible to explain this effect by the presence of a wind of about 80 miles per hour in the stratosphere, the region above the troposphere in which convection is absent and where temperature does not grow less with increasing elevation. Observations on the trails of meteorites show such deflections as would be caused by east winds in the stratosphere. If, however, we seek in these the cause of the bending of the sound wave, the difficulty presents itself that in the La Courtine observations anomalous regions were discovered both to the east and to the west of the origin of the wave. This symmetry is inconsistent with a cause acting in one direction. We are left to the discouraging conclusion that the cause of the deflection of sound waves to produce zones of silence and outer regions of audibility is not at present known. G. F. S.

Present Status of Chestnut Blight.—This very serious disease of chestnut trees has resulted not only in the diminished production of a useful nut, but also in the loss of considerable useful timber. An investigation of conditions in the southern Appalachians has recently been published by the United States Department of Agriculture (Circular 370, May, 1926). It was prepared by Messrs. Gravatt and Marshall of the Office of Forest Pathology. Much information is given as to the nature of the fungus, manner of its development and its effect on the trees. The following summary gives the present knowledge of the subject:

The chestnut blight is caused by a fungus introduced into this country on nursery stock from Asia. The organism attacks the bark of the chestnut and forms cankers. These ultimately girdle and kill the parts affected, the dead foliage remaining persistent.

A county-by-county survey, in progress since 1924, has discovered infections at the southern limit of commercial chestnut. Westward the spread of the disease has been less rapid than southward. It is believed that by 1930 more than half, and by 1935 nine-tenths, of the counties in the southern Appalachians will have reached the stage at which more than 80 per cent. of their trees will be infected.

No practical control is known, but if salvaged before deterioration sets in, the lumber from blight-killed trees is equal to that cut from live trees. Great need exists for increased cutting and use of chestnut, so that this timber may be utilized and other species conserved.

Search is being made for native and foreign chestnuts resistant to the disease in the hope of finding a tree suitable for partially replacing our rapidly disappearing stands. H. L.

Physical Theory of Meteors. C. M. SPARROW. (*Astrophys. J.*, March, 1926.)—Siderites are composed of nearly pure iron, while aerolites contain many minerals like those occurring in terrestrial

rocks. The smaller the meteor the greater is the likelihood that it is homogeneous throughout. As to the speeds of meteors the assumption of parabolic orbits carries with it a range of speeds from 16 to 72 km. per sec. On the other hand, the division of the length of path by estimated duration furnishes values of speeds ranging from 10 to 100 km./sec. In most cases the shooting stars appear between 160 and 70 km. above the earth. Generally the height of disappearance is below 120 km. The temperature of meteors inferred from their colors is from 7000° K. for the fast ones to 3000° K. for the slower sort.

Since at great heights the free path of the molecules of the air is not small in comparison with the dimensions of the meteor, the elevation of the temperature is not due to friction of the meteor against the air, but to the impartation of energy by blows of separate molecules of air delivered to the meteor. The author is able to develop a mathematical picture of what takes place during the brief luminous life of a meteor and to show that it agrees well with observed facts. He draws the conclusion that there is little change in its speed as it passes along its course.

If meteors came from outside the solar system, their speeds in their hyperbolic orbits would cause them to appear at heights above the earth greater than those at which the Leonids appear. It is rare that meteors appear at such elevations. Hence it appears that most meteors are humble members of the solar system. G. F. S.

A Study of the Smoke Cloud over Washington, D. C., on January 16, 1926. I. F. HAND. (*Monthly Weather Rev.*, Jan., 1926.)—At 8 A.M. a dust count, made at the American University, three miles northwest of the Weather Bureau, showed 876 particles per cu. cm.—about half the average number for the month. There was a cloudless sky and distant objects were rather more distinctly visible than was usual. "With a minimum temperature of 23° F., householders not only stoked their fires earlier, but used larger quantities of fuel, both of which, together with the favorable meteorological conditions, added materially to the accumulation of smoke over the city." By 10 o'clock this cloud of smoke made it necessary to have artificial light in office buildings and on the street. After the worst stage of the cloud had passed 6552 particles per cu. cm. were counted down-town. Not only were there seven times as many particles in the central district as in the suburbs, but at the latter place the particles were smaller. The cloud rolled from the city to the university campus. After its arrival the receipt of energy from sun and sky amounted to only 11 kilowatts per sq. dekametre, whereas for a clear sky it should have been 49. The electric load at 11 A.M. in the down-town section of Washington was 64,000 kilowatts. For clear days at the same hour the average was 52,000 kw. In addition to the cost for extra energy caused by the cloud of smoke, the ultra-violet part of the spectrum was eliminated from the solar radiation

received. This is of great physiological importance. "The Washington smoke cloud of January 16, while unusual for this city, was no denser than that commonly found when light winds prevail in the business centres of large cities where bituminous coal is burned."

G. F. S.

John Dalton.—A biographical sketch of John Dalton has been written by ARTHUR HOPWOOD, of the Chemistry and Technical School, Carlisle, England (*Jour. Chem. Education,* 1926, **3**, 485–491). Dalton was born at Eaglesfield, near Cockermouth, in Cumberland, about September 5, 1766, and died at Manchester on July 27, 1844. His education was completed at the age of eleven years. Later he became a school-teacher and tutor, and, for a period of six years, gave instruction in mathematics and natural philosophy in New College, Manchester. Dalton presented 116 papers before the Literary and Philosophical Society of Manchester, of which he was president from 1817 to 1844. The most important of these papers describe color blindness and the chemical atomic theory. The discovery of color blindness was announced on October 31, 1794. The paper on the "Chemical Atomic Theory" was communicated on October 21, 1803, and contained the "First Table of the Relative Weights of the Ultimate Particles of Bodies." Dalton's theory is quantitative; the atomic theories which preceded it had been merely qualitative. Earlier philosophers had assumed that the atoms of all elements have the same relative weight. Dalton declared that the atoms of the different elements are not of the same weight, and that the relative atomic weights of the elements are the proportions by weight in which the elements combine or simple multiples or submultiples of these proportions. Dalton was the recipient of the first Royal Medal awarded by the Royal Society of London. He received many honors at home and abroad. The citizens of Manchester erected his statue and endowed, in his memory, a scholarship for research in chemistry in Owens College, Manchester University.

J. S. H.

Sugar Chemistry.—The early work on the application of the methods of chemistry and chemical engineering in the American sugar industry is recounted by HARVEY W. WILEY (*Jour. Asso. Official Agric. Chemists,* 1926, **9**, pp. ii–vi) in a biographical sketch of the late Guilford L. Spencer, 1858–1925. Spencer was a member of the first class to enter Purdue University in 1874, while Wiley was a member of its original faculty. Wiley had become interested in sorghum while a boy, prior to the Civil War. He imparted this interest in sugar and its raw materials to his pupil. Spencer pursued graduate studies at the University of Michigan and in France, with special reference to sugar technology. When Wiley became Chief of the Division, later Bureau, of Chemistry of the United States Department of Agriculture in 1883, he secured Spencer as a colleague in the Division. They conducted experiments on a commercial scale

in experimental factories, on sugar cane in Louisiana and on sorghum in Kansas. A third experimental factory was located in Florida. As a result of their researches, the sugar planters of Louisiana organized a sugar experiment station in 1885.

A plant for the manufacture of sorghum sirup on a commercial scale was operated near Lafayette, Ind., in the early seventies of the last century by Wiley and several friends. J. S. H.

Composition of Glauconite.—The mineral glauconite occurs in every geological age from the Cambrian to the present. The pre-Cambrian rocks contain greenalite, a related mineral. To-day glauconite is forming on the sea-bottom. Its potassium content makes it of possible value as a source of that element for the nutrition of plants. CLARENCE S. ROSS, of the United States Geological Survey (*Proc. U. S. Nat. Museum*, 1926, **69**, Article 2, 1–15), has determined the composition of glauconite. It is an isomorphous mixture of two complex silicates, each of which contains water, potassium, magnesium and ferrous iron, aluminum and ferric iron, and silica. The one silicate has the formula: $2H_2O.K_2O.2(MgO,FeO).2(Fe_2O_3, Al_2O_3).10SiO_2 + 3H_2O$. The other silicate has the formula: $2H_2O.K_2O.(MgO,FeO).3(Fe_2O_3,Al_2O_3).10SiO_2 + 3H_2O$. Both silicates probably are derivatives of metasilicic acid. J. S. H.

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